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The Plane Table.

By

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1865. Assistant U. S. Coast Survey

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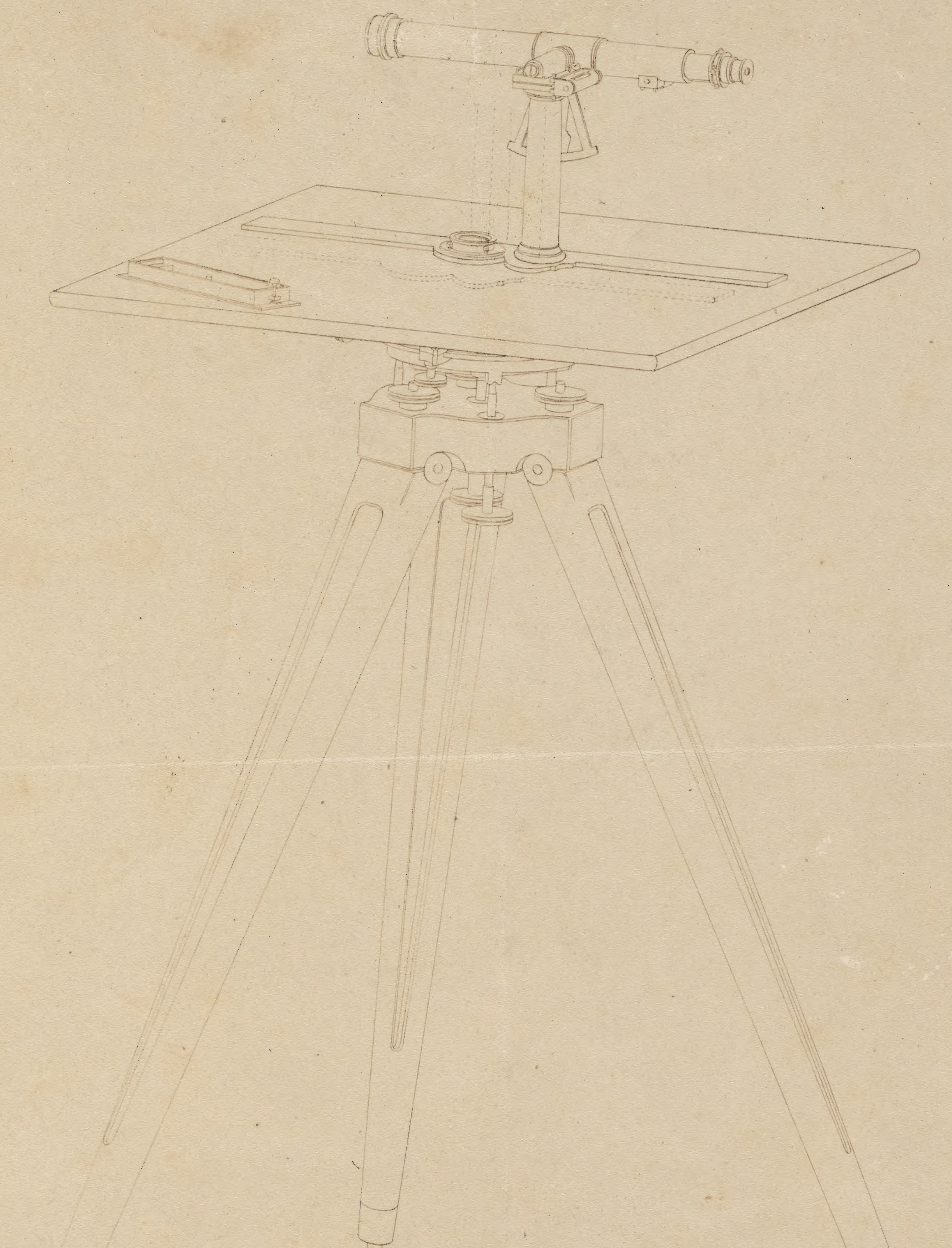

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Diagrams Etc.

The Plane Table.

Diagrams

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1.

Introduction.

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roductn.

The following description of the Plane Table, and the accompanying notes upon its employment in the field are designed for the use of beginners.—

There has been a careful avoidance of those comparatively abstruse questions which are of necessity embraced in a thorough treatise of topography in its relations to other branches of geodesy, the object being simply to present, as clearly as may be, certain primary rules and suggestions without a familiarity with which the student can hardly hope to advance.—

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A short account of the origin and history of the instrument, it was thought, might also prove of interest, and, perhaps, instructive.

As this paper is by no means exhaustive it is hoped that there may yet be compiled a more comprehensive manual, embracing all the tables, rules, general and specific, as well as full and clear discussions of all problems and theories bearing upon the subject, affording what is at present so greatly needed, a Text Book which shall be reliable, devoid of irrelevant matter, and adapted to the

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improved condition of the Plane Table, the comprehension of the youthful scholar and the service and requirements of the experienced topographer.-

The necessity for a work of this kind has long been felt. Professor Benoît, of the School of Application of the Royal Staff corps of France, to whom further reference will be made, in the preface to his work upon the Plane Table, published in Paris in 1822, remarks:- "Pourquoi donc la topographie et la "géodésie, la théorie des levés, des "batimens, des usines, ect, et l'art "d' exécuter les dessins qui en dependent,

trod^{n} "sontils encore si peu repandus? C'est, "ne craignons pas de le dire, c'est que "les écrits que nous possédons sur ces "matières sont ou insuffisans, ou "trop prodigues de science." And in the Topographical and Military Memoir, also published in the first quarter of this century at the Dépôt General de la Guerre, referring to certain ~~some~~ treatises upon the subject which had appeared in previous numbers of the same work, the editor observes that "some have, with "little method or accuracy, the fault "of not having been kept on a level "with actual experience, and the ideas "presented in the others are for the

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"most part either incomplete or touched "upon too briefly, and not being isolated or disencumbered, are not given "in such a manner as to facilitate "either study or practice. A work is "needed on this subject classifying "and combining the different branches, "simplifying the rules, at the same "time enriching them with the results "of improved methods, instruments "and processes of practical geodesy, "giving in this respect a clear, exact "and complete résumé, extracting "from all former works all that is "essentially useful to render the "practical working sufficiently plain "as to assure its advancement and

"promote its progress."

In a great measure this holds good at the present time. Heretofore, for the greater part of their information, the beginners have been obliged to depend almost entirely upon the more experienced Chief of party, there being no authority to which they could turn with any reliance in case of doubt or difficulty for directions or relief, and such tables as have been formed, and the formulae incidental and necessary to their work, have never been brought together in a convenient and available form. While most of them, when thrown upon

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their own resources, have been able to use the instrument successfully so long as no embarrassments have arisen, when they have appeared, as at times they will, they have been forced to trust to their own inexperienced judgment to overcome them and either to go on in an unsatisfactory way, or to suspend entirely for want of a proper monitor.

As a step in the desired direction this article has been prepared. It purposes to be a somewhat systematic arrangement of the results of the experience of some of the best topographers of the Coast Survey, together with such suggestions

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and information from various authorities as are found to coincide with absolute practice in the field.

So far as an examination has been made, which, however, for many reasons has not been as thorough as could be wished, it has been found that in most English and American works the subject of Plane Table topography is treated of in so brief and cursory a manner as to make it evident that the instrument has not generally been considered as possessing those qualities for the execution of topography of which the operations of the Coast Survey have proven it to be capable. It is usually referred

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to incidentally and rather slightingly, and apparently regarded as adapted to preliminary or rough work only, and indeed this position is true when the instrument is constructed as commonly described.

By some German and French authors, however, among whom it now occupies a high position, it is written upon more in detail and more satisfactorily, but even these treatises are found either adapted to an earlier and more imperfect stage of the instrument and of topography, or to include so much that is purely mathematical, combining a great deal that is extraneous to practical work

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with theoretical discussions beyond the comprehension or necessities of the beginner, as to be of but little service.

Should this paper serve to lead in any way to the preparation of a more elaborate work compassing the needed requirements, and prove an assistance, however meagre, to the student of Plane Table topography, it will have effected its object. –

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Historic Account
# of the
Plane Table.

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In tracing the history of any geodetic or mathematical instrument, we ~~which~~ are carried ~~[illegible]~~ very far beyond the limits of the last ~~our own~~ century, it is ~~very~~ difficult to fix an exact date to its origin, or to give, with certainty and justice, the name of the inventor. Most instruments of the kind have been found to be not so much the immediate off-spring of one mind, as the result, 2 — (according to the requirements of the times and the progress of ~~[illegible]~~ ~~mathematical knowledge~~ science toward exactness of methods) — of the gradual application of ~~new~~ improvements, upon ~~to~~ older devices, the latter in their turn having held their places as improvements upon

t of Pl. T. some former and still more remote inventions.

In following back, therefore, the ~~account~~ history of the Plane Table, we are brought ultimately to the ancient Astrolabe and Gnomon, and it is doubtful if further investigation would not lead us, [as the true 2 starting point], [1 to the ~~first~~ original idea of simply drawing or reducing ~~any~~ plans or maps ~~whatever~~ upon plane surfaces. 1]

The credit, however, of the invention of the Plane Table, - under the Latin name of *Mensula Praetoriana*, - has been definitely given to *Johann Praetorius*, *Mag. Phil.*, who was born at Joachimsthal in 1537, and died at

e Acct. of
Table.

Altdorf, October 27th 1616. He was, at first, instrument maker at Nürnberg, and then lived successively in Prague, in Vienna (where he gave lessons in mathematics to the Emperor Maximilian II) and in Krawkow, and was Professor of mathematics at the Universities of Wittemberg and Altdorf. He is said, also, to have originated the water level, and is the author of two mathematical treatises.—

Beyond the assertion of his pupil, Schwenter, upon whose testimony this credit rests, and ~~the~~ its ~~repetition of the same~~ conformation by a French author; who dates the promulgation of ~~A~~ the invention, vaguely, somewhere in the latter part of the sixteenth

of Pl. Tab.*

century, we have been unable to discover any ~~work or~~ record substantiating the claim.

From the fact that at very nearly the same period, a book, now extant, ~~and readily obtained~~ though rare, was written upon the subject, in which the Plane Table is treated of as an entirely new and original conception, and as the author held a respectable position among scientific men, both he and his work were probably not unknown to Praetorius, and as the latter does not appear to have questioned this authors right to ~~the credit~~ be regarded as of the inven~~tion~~tor, the probability is that it justly belongs to him. At any rate

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as it is the first detailed and authentic account of the instrument we have been able to discover, it is worthy ~~of~~ ~~not well to pass it by without some~~ notice.

In the year 1625, "at the house of Ludwig Koenig," in Basle, Switzerland, there was published, in the antique German of the day, a quaint little volume with the following title:-

"Fabrica et Usus
"Instrumenti Chorographici:"
"That is, a new
"Planimetrical Statement,

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t of Pl. T.

"How by means of a light and simple
"Instrument to draw, on a reduced scale,
"any town, garden, pond or landscape,
"in its exact situation and proportions.

"Embellished and illustrated by fifteen clear
"and beautiful engravings on copper.

"Published for the benefit of all friends
"of science, but especially architects, and
"those who use the compass and rule."

It is inscribed, with much verbiage and a long array of titles, on the 14th day of January, Anno Domini 1607, "To the High "Born Lord, His Imperial Highness

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of N. T. "Maximilian Archduke of Austria," by His Grace's humble servant, Leonhard Zubler, Burgher, at Zurich.

In the dedication, after a brief reference to the usefulness and readiness of adaptation to practice of mathematical science; the author regrets the prevailing unskilful and negligent use of geometrical demonstrations, whereby error results, and complains of the tendency of scientific men to conceal, for their own purposes, whatever new discoveries they may have made; and also of the general jealousy prevailing among them, "as "though it were given to them alone, "from God, to understand this science";

t of P. T.

and hence "it is no wonder that it is "held in somewhat slight estimation "by many." But, in consideration of the *interest* which His Grace has manifested for the "laudable exact sciences," the worthy burgher wishes most humbly to offer him "the present, though poor, yet correct and "useful Instrument *by which one can* "*sketch on a board in reduced size,* "castles, landscapes, meadows, ponds, "or even an entire camp, in its extent "and true proportion, and also obtain the distance to each very neatly and accurately by means of compass and rule."

The engravings in this

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interesting little work presents a very good idea of the costumes and some of the customs, camps and modes of fortification of the time., ~~and~~ The birds-eye perspective, though coarse, is not devoid of artistic merit and serves to show ~~delineates~~ quite clearly the method of employing in the field, the instrument treated of.

In the Preface, we learn from Master Zubler, that the "beginning of such an instrument" was shown to him by his "dear fellow "burgher, Master Philip Eberhart "stone mason" and he also refers to the "ingenious proportional com-"passes which the accomplished Herr

of. Pl. T. "Jost Buerge of Switzerland &c &c, invented!"

In Chapter 2nd the instrument is described as consisting of a board one and a half feet square, and one and a half inches thick, with a stand three or four feet high. A rule about two feet long, ~~with~~ having a needle in one end fastened by wax, and ~~another~~ another needle fixed in the board "give the sights for the meas-"uring undertaken." In case "it is not "convenient to have a stand, a stone, "stick, or stool" is recommended, with the injunction, however, that care should be taken to "make it firm".

A sheet of drawing paper was then fastened to the Table, also

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of Pl. T. with wax. The horizontality of the board was not considered necessary while in use, provided it sloped equally at all stations, (a matter of judgment it is presumed) as in sighting from a mountain to a valley, or vice-versa.

In Chapter 12 the method of constructing a more elaborate instrument, upon the same principle, is given, with the addition of a compass and magnetic needle upon the face of the board.

The Alhidade, (Arabic *Al* article, -*hadat* a rule, from *hadaj* to guide on the right way. Latin *Alhidida*, *Alidada*) was a simple rule with two sights

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"such as are used in the quadrant, or "better 2 points, or needles, which stand "upright on a straight line."

The description concludes:- "Divide the movable rule as follows; - "first make a line through the centre "and divide one portion into 200 parts "or points, and the other into 1000 parts. "The Instrument is then complete."

The modern topographer will recognise in these descriptions, in the brass rule the rude original of our present al~~h~~idade, with ~~the~~ a scale of equal parts engraved upon it, and in the magnetic needle the ~~present~~ declinatoire.

It is to be presumed that this

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is the first published account of the ~~invention of the~~ instrument from which our present ~~more perfect~~ Plane Table has been gradually developed ~~sprang~~. It is possible that Zubler had derived some hints from the ~~ancient~~ Astrolabe of the Astrologists, which was merely a projection of the sphere upon a plane surface, having ~~with~~ a graduated rim, and sights for taking altitudes; ~~and~~ in fact the author refers to it indirectly, as a "fine and "artistic" instrument.

The construction of projections, and the system of working with points previously determined by the measurement of horizontal angles, were unknown at this time.

The work was executed entirely on the principle of intersecting lines, and from ~~with~~ a plotted base, which was measured with wooden rods or a knotted rope; ~~and~~, In a survey embracing a large area of country, — probably intended as reconnaissance, the author naively remarks, "if the desired spot is far off "some countryman should be asked "about the distance", and this was to be divided into rods and feet and employed as the base line! –

Leonhard Zubler was born in 1563 in Zurich and died at the same place Oct: 9th 1609. – He was the author of several other works, not all confined to the consideration

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t of N. T. of geodetic subjects.

Seventeen years after the publication of the above; but in a much inferior style of typography and engraving, a larger and more pretentious work was issued under the following title:–

"*The Compleat Surveyor*, Containing
"the whole *Art* of Surveying of Land.
"By the Plaine Table, Theodolite, Cir-
"cumferentor and Peractor and other
"Instruments. After a more easie, ex-
"act and compendious manner then
"hath been hitherto published by any:
"the *Plain Table* being so contrived

l of Pl. T. "that it alone will conveniently perform
"whatsoever may be done by any of the
"forementioned Instruments, or any
"other yet invented, with the same
"ease and exactness, and in many
"cases much better &c. &c. &c. —" × × ××

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"By William Leybourn.
"London, Printed by R. & W. Leybourn
"for G. Sawbridge at the Signe of
"the Bible, upon Ludgate Hill MDCLVII."

This heavily bound quarto is printed in ~~black letter~~ old fashioned black type, and is prefaced with a portrait of the author stamped as "Vera Effigies." The typographical errors are numerous and the diagrams

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present the appearance of the rough efforts of a school boy.–

In the preface Mr. Leybourn remarks:– "I have given such
"directions for the making of the Plain
"Table and furnished the Index and
"other parts thereof with divers necessarie lines for several occasions, so
"that it being made according to the
"directions there given, it is the most
"absolute and universal Instrument
"for all occasions yet ever invented;
"for by it may be performed whatsoever may be done by the *Theodolite*
"*Circumferentor* or *Peractor*, with the
"same facility and exactness, and in
"many cases better as in the par-

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"ticular uses thereof will plainly appear".

Still further on he writes;-

"So that this Instrument onely is sufficient for all manner of practices whatever". And yet, though showing a ~~considerable~~ marked improvement upon Fuller, ~~this~~ the instrument,* of which the writer speaks so enthusiastically, ~~as~~ constructed by the rules he furnishes, would now be regarded as scarcely adapted to the execution of a fair topographical reconnaissance, notwithstanding the rather comprehensive claim put forth in Chapter 1, that "having that one Instrument (made "according to the following directions) "you shall have need of no other for

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t of Pl. T. "the due and exact and speedy performance of anything belonging to the "Art of Surveying."—

The Plane Table of Leybourn consisted of a parallelogram fourteen and a half inches long and eleven wide, composed of three boards readily taken apart for convenience of carriage. A "joynted frame," so contrived as to be put on and off at pleasure, served to bind these boards together and also to fasten a sheet of paper upon them, and having upon it, "neer the inward ledge, Scales of "equal parts on both sides for the

t of P. T. "speedy drawing of parallel lines upon the paper."

"There belongeth also to "this Instrument a socket of brasse "to be screwed on the back side of "the Table into which must be put "the head of the three legg'd Staff, "this Staff ought to be joynted in "the middle, so that it may be "more portable. For the socket it "may be a plain one; but a Ball "and Socket with an endless screw "is the best of all, for by help thereof you may place the Table (or "any other Instruments) either "Horizontall, Verticall or in any "other position."

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The alhidade, or, as he styles it, the Ruler or Index, is somewhat more complex than that described by Zubler, for ~~and~~ it appears that it had already been ~~already~~ much ~~considerably~~ improved upon. It is described as about sixteen inches, or more, in length, – being long enough to reach from corner to corner of the board, – about two inches in breadth and one third of an inch thick, and carrying two sights, one of them twelve inches long ~~in length~~ and the other six. Upon the top of the shorter sight is placed a brass pin, and also a thread and "plummet," to be used for ~~the same~~

in placing ~~purpose as the present level, to place~~ the board horizontal. Through the longer sight is a slit for the greater part of its length, and both ~~the two~~ are erected perpendicularly upon the index "in such sort that the wier on "the top of the shorter sight, and the "slit on the longer sight stand precisely over the fiducial edge of the "Index. The space or distance of these "two sights from one another is to be "equal to the divided part of the "longer sight." Upon the longer sight is placed a brass vane, movable up and down at will, through which is a small hole "answerable "to the slit in the same sight and

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"the edge of the vane. By these sights
"thus placed on the Index there is
"projected the Geometrical Square
"whose side is the divided part of the
"long sight (or the distance between
"the two sights.) In the middle of
"the long sight (through the whole
"breadth thereof) there is drawn a line,
"called the line of level, dividing the
"side of the projected Square, into two
"equal parts, also the same side is
"on this sight divided into a hun-
"dred equal parts, which are num-
"bered upwards and downwards, from
"the line of level, by fives and tens
"to fifty, on either side, which di-
"visions are called the Scale. There

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"is also on the same sight another
"sort of division, representing the
"hypothenеusal Lines of the same
"Square, as they increase by Unites,
"and are likewise numbered upwards
"and downwards from the line of
"Level, from one to twelve; by 1, 2, 3, &c.
"Sometimes signifying 101, 102, 103, &c,
"these divisions shew how much any
"hypothenеusal or slope line drawn
"over the same Square exceedeth the
"direct horizontal line being the side
"of the same Square. On this sight
"there is a third sort of divisions rep-
"resenting the degrees of a Quadrant
"(or as many as the same sight is
"capable to receive, which are about 25)

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of. P. T. "numbered from the line of Level up-"ward and downward by fives and "tens to 25, which divisions are called "the Quadrant.–"

In this form, the author states, the Plane Table had heretofore been constructed, by which we see an advance had ~~already~~ been made in a comparatively short time; among others the very important,–though not in the manner proposed, ~~not~~ very exact improvement of taking vertical heights by means of the al~~h~~idade, among others, having been introduced.–

Having thus described the Table and al~~h~~idade after what he styles the "vulgar way," he proceeds

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to give some further additions, or "a *metamorphosis* of that Instrument, "making it the most absolute and "universal Instrument ever yet invented."— 1st He recommends that the frame before spoken of be so fitted to the board that it may go on easily with either side upward, and that one side be marked with the 180° of a semicircle, from a centre on the superficies of the board, the degrees being numbered from left to right "with the centre next you. "These degrees thus inserted are excellent in wet or stormy weather "when you cannot keep a sheet of "paper on your Table either in re-

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t of P. T.

"spect of rain or winde, also these "degrees will make the Plain Table "an absolute Theodolite &c. &c. –"

2nd An arrangement of sights upon the rule by means of a slit and thread on each sight that one ~~can~~ may observe backward and foward without reversing the instrument.

3rd A side sight upon a pin on the side of the back sight, working in arc.– This was probably the first attempt of the application of the vertical arc for taking heights with the Plane Table.– To it was added a very rude scale upon the rule, called "line of tangents".

4th The attachment to the side of

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the board by means of two screws, of a box and needle, to be readily removed and replaced, containing a card divided into 360°; a closer approximation to the present declinatoire than that of Zubler.-

The directions given for putting the Table together are as follows:- "When you would make "your Table fit for the field lay the "three boards thereof together and also "the ledges at each end thereof in their "due places, according as they are "marked. Then lay a sheet of white "paper all over the Table, which must "be stretched over all the boards by putting on the Frame, which bindes both

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of P. T.

"the paper to the boards and the boards
"one to another. Then screw the Socket
"on the back side of the Table, and
"also the Box and needle in its due
"place, the meridian line of the card
"(which is in the Box) lying parallel
"to the Meridian or Diameter of the
"Table; which diameter is a right
"line drawn upon the Table from
"the beginning of the degrees through
"the centre, and so to the end of the
"degrees. Then put the Socket upon
"the head of the Staffe, and there
"screw it. Also put the sights into
"the Index and lay the Index on
"the Table, so is your instrument
"prepared as a plain Table &c. &c."

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The following will conclude the extracts from this work, of which sufficient have been given to show the progress made thus far in the construction of the Table. "The frame of the Table being "graduated according to that description will be an absolute Theodolite, and perform the work thereof with the same facility and "exactness, and whatsoever may "be done by the limbe of the Theodolite, the same degrees on the "frame of the Table will as well "perform. Likewise the Index and "Sights, together with the Box and "needle, being taken from the Table,

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of P.T. "and screwed to the Staffe (as in the
"description thereof it is so conve-
"niently ordered) will be an absolute
"Circumferentor, and in some re-
"spects better than the ordinary
"one hereafter described, because
"the Sights thereof stand at a
"great distance, so that thereby
"the visual line may be the better
"directed. And this Instrument
"(as now contrived) though it be
"called the Plain Table only, yet
"you see that it contains both
"the other, and therefore in ad-
"vising any man to the use there-
"of chiefly, I do not confine him
"to one but to all Instruments, and

of P.T. “therefore do not contradict my for-
“mer expression. Besides there is an-
“other great convenience which doth
“ensue by the degrees on the Table's
“frame; - for in taking the plot of a
“field according to the following
“directions by the Plain Table, you
“may at the same time work by
“the degrees on the frame of the
“Table, If at the drawing of every
“line you observe the degrees cut by
“the Index, and note them upon
“the paper. This I say is a great
“convenience, for at one observation
“you perform two works with the
“same labor, as in the uses of these
“Instruments severally a Surveyor by

33.

of P.T. "this contrivance, which with practice "will appear of themselves."

Leybourn was ~~both~~ a writer of some note on mathematical subjects, as well as a publisher of the works of others, and in his books he acknowledges his indebtedness to many previous, authors who had written upon the Plane Table and kindred ~~subjects~~ topics, showing that it had, even in that day, ~~already~~ become an instrument of some importance.

We now find the Plane Table treated of in most works upon geodesy, under a great variety of forms, many of them bearing but little resem-

of Pl. V.

blance to those already referred to, or to the one in present use. Scarcely any improvement in construction appears to have been made, the inadequacy of the support to give and preserve a fixed horizontal position, being a chief difficulty to its use as a refined instrument, and the character of the alidade, and its mode of employment, rendering (impossible) (the production of close results.)

As giving an idea of some of the forms under which it was used, as well as the position it occupied as a surveying instrument toward the middle of the last century, we will refer to a rather ~~neatly~~ small

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t of P. T. ~~arranged~~ and, quite ~~small~~ neatly arranged volume, illustrated with tolerable wood cuts, which appeared in France under the following title:—

"Method of Drawing
"Plans and charts
"of the Earth and Sea
"With Instruments of all kinds,
"and without Instruments;—
"By Jacques Ozanam
"New Edition.
"Paris. Rue Dauphine
"By Charles-Antoine Jombert.
"Publisher to the King of works on Ar-
"tillery and Engineering, at the sign

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of P.T. "of Notre Dame.

1755

"By authority of the King."—

This book is made up, mainly, of a criticism upon a work by Mr. Ozanam,—the criticisms being sometimes favorable and sometimes ~~otherwise~~ the reverse;—; combined with a sort of running treatise upon special and general surveying.

¶ In chapter III, After a description of other instruments,—(among which is one which the author styles the "Arc" the name of which is sufficient to explain its use)— ~~in chapter III.~~ he says ~~he says~~;— "The plane table is an in-

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t of P. T. "strument which is used like an arc, but
"with this difference, that this instru-
"ment only gives the angle as it is,
"but not the number of degrees in-
"cluded in it.– It consists of a very
"smooth board of wood or a plate
"of brass, circular in form and about
"a foot in diameter. In the centre is
"a small upright cylinder, which is
"the pivot about which a rule or
"alidade turns, as in the arc, having
"at its extremities two sights, or a
"small telescope instead of sights.
"This rule should have a straight
"line corresponding exactly to the
"centre of the cylinder, which serves
"as a pivot. You have several cartoons

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"or sheets of paper, of the size of this
"board, which are pierced in the mid-
"dle by a hole of the size of the cyl-
"inder or pivot of the instrument; so
"that one of these cartoons may be
"placed on the pivot, and fitted ex-
"actly to the plane table, and the
"alhidade placed above it. These car-
"toons are fastened to the plane table
"by means of a little point which pier-
"ces them slightly, and which is near
"the edge of the plane table. Careful
"and accurate people use, in order to
"cut their cartoons precisely the size
"of the inner circle of the plane table,
"a pair of dividers, one of the points
"of which is sharp."

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"To observe with this in-
"strument, place the plane table on its
"base by means of a knee, as with the
"arc, or on something stable, so that
"it need not move when the alhi-
"dade is turned: then take sight by
"the sights or telescope at some dis-
"tant object; and the rule remaining
"fixed in this position, draw on the
"cartoon, near its extremity, a line a-
"long the rule, corresponding to the
"centre of the instrument, and write
"on this line the name of the place
"at which you have taken sight;
"then turn the rule to another object,
"and draw the line leading to it,
"as before; these lines always setting

"out from the centre of the instrument,
"like the radii of its circle. Having
"thus taken sight at all the places
"which can be discovered from the
"place where you are, write near the
"centre of the cartoon the name of the
"place where the observation is made,
"and these places from which an ob-
"servation is made are called stations.
"You have on this cartoon all the 58-9
"angles of position of the places to
"which you have directed the sights
"or the telescope, in relation to the
"places where the observation is made.
"This method of obtaining angles of
"position is not liable to the errors
"which may be committed in reckoning

1.

of P. T. "the degrees and minutes of the limb of
"the arc."

"As many cartoons are gen-
"erally changed as different stations
"are made, or angles observed, but as it
"sometimes happens that cartoons fall
"short in certain places where there are
"no means of procuring them, it is
"then necessary to economize the few
"which one has, one may without hes-
"itation be made to serve for half a
"dozen by making three circles on each
"side which should be equal in all re-
"spects. As the instrument is supposed
"to be a foot in diameter, these circles
"will be two inches apart from each
"other, and it is in this space of two

2.

of P.T. "inches that the observations of each
"line are written. For instance, the
"cartoon being fixed on which you
"have drawn with ink three circles, you
"should begin the first observation
"at the largest circle, and follow to
"the smallest; and instead of draw-
"ing the lines of position from the
"first station to the centre, draw
"them only in the space which occurs
"between two circles; thus without con-
"fusion or embarrassment you have on
"each side of your cartoon three stations,
"or even more, if you wish, according
"to necessity, on which, as we have said,
"the name of the place where the sta-
"tion is made should always be writ-

3

of P. T.

"ten in the centre, when only one station "is made on each cartoon: but when several are made, these names should be "written parallel to each of the circles "and near the edge, in larger characters "than the rest, and the names of the "points observed parallel to the radii." It will be seen that this ~~is~~ was merely the mechanical measurement of angles in the field upon a series of circular cards, or cartoons, fixed to the Plane Table, one being employed at each station, the lines including the angles were taken to be ~~employed~~ used in plotting ~~in the office~~ in the stations, in the office and [illegible] in combining the work upon a large chart. The cartoons ~~are~~ were, in fact, protractors, the angles upon

which ~~have been~~ were measured graphically ~~in the field~~, without any record of the degrees and minutes, and they ~~are~~ were subsequently used in protracting the general map. Of course a measured base ~~is~~ are requisite, only to be used, however, ~~only~~ when projecting the final sheet.

The writer says this instrument is very little used in "particular" or special surveys, but is expeditious and correct in "drawing charts". The operator is directed to add details, but whether in a field book, or upon the cartoons is not stated, - and is enjoined to "observe with accuracy". He further remarks, ~~and indeed the admonition should always be heeded,~~ - that "with-

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of P. T.

"out a little care, with the best instrument in the world nothing of value "can be done, and the very smallest error "should not be overlooked because its "effects reach very far, and it is con-
~~and~~ this admonition is is as justly pertinent now
"stantly augmented;" as then.

He refers to the graduation of the edge of the Plane Table, so that the angles, when taken, may be marked in degrees and their subdivisions, in which case it becomes nothing more than L~~a~~eybourn's "Theodolite" before referred to; but "to tell the truth" he regards it of "no great use;" on the contrary, it is objectionable as adding to the expense.

46.

t of P.T.

In Chapter IV. we have the description of another Plane Table "less complex" than ~~one~~ that just treated of,+ which, — save perhaps in being less roughly made and being supported by legs and a knee or joint, — is but little superior to the original ~~instrument~~ of Lubler. It is a board twelve or fifteen inches square, "placed in a "frame, the use of which is to enclose "the sheet of paper on which you "work. — This instrument is placed on "a stand with three feet, and has "neither sights nor telescope, pins "being used for taking observations. "Having your scale placed on the "edge of the frame you set down

7.

t of P. T.

"immediately the lengths and distances. &c. &c." After giving directions for its use, in which the system of intersections from a measured and plotted base is employed, and furnishing two examples by which we find, as in the circular instrument, that many sheets of paper are necessary to complete one map, - M. Jombert arrives at the conclusion that it cannot be used with precise results, and "that often the points sought "are without the square of the in"strument, and it has frequently the "fault of being inexact; for the pins "are difficult to place plumb; and "when the same hole has been used

48.

t of P.T.

"three or four times, it becomes enlarged "and will not hold the pin: besides, in "marking the angles, if you come upon "an irregularity in the grain of wood, "the pin avoids it, slips, and pricks "on one side, between two "waves;" after "which, in drawing the radius with "the rule, it happens that you find "yourself outside the point, or less "on one than the other, so that these "operations are never exact". "Further, "if your plane table is not quite hor"izontal in taking these radii, this "again causes errors." "Nevertheless" he says, "I do not condemn it entirely, "in that it is easily made, and when "you require it, and are without an

49

t of P. T. "instrument, the first carpenter can "make you a plane table and pins are "to be found anywhere."

He remarks, in concluding his observations on this form of the Plane Table, that his author (M. Ozanam) "puts it to every kind of use "and makes it his main dependence", and takes this rather singular position:– "Moreover whenever one can "work without an instrument, he "should by no means use one!"

The last paragraphs of this chapter, referring to the claims put forth for one form of the Plane Table as a "Universal Instrument", are not without point.– "For my

50.

2 of P. T.

"part, I think that the most reasonable course to take, is not to give a "compass to any instrument beyond "its capacity; for in this way, all of "them will be universal instruments, "and I do not know one of which it "is not claimed on paper that it can "be used for all things. As I have "already said, the difference between writing on paper and working "on the ground, is, so to say, greater "than that between # saying and doing. They have even been so far as "to wish to teach us to measure the "altitude of a cloud which moves at "the caprice of the wind!" After expatiating upon the presumption of

51.

l of P.T. this claim, he concludes "that the desire of saying something new enters "into it more than the accomplishment "of any valuable result, and that a "skilful man feels in his conscience "that it is a superfluous chapter "which he has added to his book."

Except in general principles it is seen that the instruments thus described differ essentially, from the present Plane Table, and the account of them is only given to show some of the varied forms under which attempts have been made to adapt it to its legitimate use.

Chapter V gives a description and an example of the "Uni-

52.

of P. T. versal Instrument," another form of the Plane Table, with two rules,—but not greatly differing from that of L~~a~~eybourn,—which it is hardly worth while to describe here and which M. Ozanam claims "would solve very readily and "very accurately all the problems of "practical geometry."

The author, however, sees many disadvantages in its ~~use~~ employment; and prefers the round instrument before spoken of. Nevertheless, in the last words of the chapter, with which we will end the notice of this work, M. Jombert comes to the final conclusion "that without a moment's hesitation "I should prefer the Plane Table well

t of. P. T. "graduated and provided with two good "telescopes, knee, &c. to all other instruments "whatsoever."

There is but very little in the various desultory scientific articles and books upon Surveying ~~which~~ affording any new ideas respecting the Plane Table ~~subsequent~~ ~~after~~ ~~to~~ from this ~~period~~ ~~[illegible]~~ time, down to a comparatively recent date. Occasionally some addition, simplification or complication ~~to the instrument~~ is suggested; but in its general features ~~it~~ the instrument is found to be very little advanced toward adaptation to close and minute work till the pres-

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of P. T.

ent century.

Poussaint's voluminous and useful "Treatise on Topography" published in Paris, in 1820. gives a description of Cugnots' Plane Table, to which he recommends the addition of a tangent for delicate horizontal movement, but presents no new points of interest.—

A valuable and comprehensive work, however, appeared in France in 1822, containing a very complete discussion of the preliminary investigations necessary to a clear understanding of the theory of topography, of the use of the instrument accompanied by a full description of it, and the solutions of numerous problems

55

l of P. T.

involved in field practice. - It is a book in every way creditable ~~to the author~~ and of excellent service as a text book for the Plane Table of that day. It will be seen, however, that ~~that~~ the portion of the volume relating to the instrument itself and its employment, owing to the great ~~improvements~~ advance which ha~~ve~~s been made in all that relates to this branch of the subject, would be of but little service at the present time except perhaps that a study of the accompanying problems might serve a good purpose as a training for the mind of the student. - This work, handsomely gotten up, with clear and well executed illustrative diagrams,

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t of P.V. bears the following title:-

"Cours Complet de Topographie
"et de Géodésie a l'usage de L'École
"d' application du Corps Royal d'Etat
"Major. Par P. M. N. Benoît, Professeur-
"adjoint de topographie et de géodésie
"a l'École polytechnique, ex-lieu-
"tenant au Corps royal des ingénieurs-
"géographes militaires, et lieutenant au
"Corps royal d'etat-major.- Première
"Livraison. Traité des Levés a la
"Planchette précédé de généralités sur
"les descriptions graphiques des corps
"et du globe terrestre en particulier.

"Dat veniam scriptis quorum non gloria nobis
"Causa, sed utilitas officiumque fuit.
Ovid.

57.

t of P. T. "A Paris, chez Barrois L' Ainé, Libraire Rue "de Seine, No. 10, F. S. G. 1822."

skip a line —
In the preface, the author remarks " Pourquoi etc (~~page~~ - 3 4th line from bottom and ending) "— de excuse"
then skip a line —

As the Plane Table of M. Benoit was adopted by the majority of the officers of the Royal Corps of Military and Geographical Engineers of France, and as it appears to have possessed all the improvements and advantages known up to that time, thus illustrating another interesting step forward in the history of the instrument, we will give a description of it, abridged from his pages.

It consisted of a rectangular board or Table about 0. 6 of a

t of: P.T.

metre or 23.5 inches square, upon which was fastened, with mouth glue, or small flat headed tacks; or by means of rollers of the length of its two opposite sides, kept in their position by ratchets or screw nuts; – the paper on which the chart was to be designed. – This Table rested upon a smaller ~~square~~ also square Square board, which sustained it, and to which it was firmly held underneath by means of four screws at the corners, easily loosened, so that the Table could be removed when desirable. – To the underside of the second board was immovably fixed a circular disc of wood, having for its centre the centre of the instrument itself, and this

59.

ct of P. T.

rested on a like wooden disc, projecting somewhat at the periphery beyond the upper one, the projecting edge being formed of a brass ring. The upper disc and, of course, the two boards which it supported, had a circular horizontal movement upon the lower one about a bolt running through the centre of both. – The bolt was permanently fastened, at its upper end, to the lesser or supporting square board, and was capable of being made fast~~ened~~ or loose~~ned~~ at will at its lower extremity, by means of a large-headed female screw which clamped upon a brass cylinder or socket, projecting somewhat below

t of P.T. the lower disc, and through which the bolt ran.—

A tangent screw was suspended at one end from the under face of the smaller board, and at the other end it ran through a mov~~e~~able clamp, which secured it to the brass flange before mentioned.

Two stout tongues projected downward, at right angles, from the lower disc, with their faces parallel, and were firmly fixed at their upper ends. At their lower extremities these tongues were connected by a wooden cylinder,-revolving on its axis by means of a bolt extending through its length,— with a clamp screw at the end, and

61.

t of P. T.

having another cylinder running at right angles through its centre, the two being turned from one piece of wood.— The second cylinder also permitted a motion on its axis by means of a bolt and screw, the axes of the two being a little apart to allow the passage of the two bolts without interference. This latter arrangement, called the "knee", was "a piece of mechanism "adapted to bringing the table in a "horizontal position and permit it "afterwards to revolve about its centre "without losing its horizontality," or in other words the levelling apparatus, a small level being placed upon the Table for this purpose. In the ab-

62.

t of P. T.

sence of a level the use of a small, perfectly spherical ball, placed upon the Table, is suggested.

The whole apparatus was supported upon three wooden legs.—

The al~~t~~idade was somewhat similar in its general construction, though lacking in some essential points, to that now used in the Coast Survey. It was without an attached level or vertical arc and liable to get easily out of adjustment.

It is evident from the unstable support given to the Table and discs by the tongues,— from the weakness consequent upon undue leverage

Skip a line after "perfection"

*This work has passed through many as editions, and from the fact that I have in my possession a copy issued so late as 1865, it is possible ~~I presume~~ that it may still be used as a text-book in the engineering schools of France.

(Skip a line)

t of P. T.

of the tangent screw; - from the fact of the material being mainly of wood, instead of metal; - affording but a very faulty arrangement for obtaining and maintaining its horizontality, - and from the inadequacy, in many respects, of the al~~t~~*idade; - that the instrument here described would not now be deemed adapted to the execution of finished topography; M. Benoit, however, remarks in summing up his conclusions that the Plane Table "has received since its invention to "the present time such improvements "that it is difficult to believe that "it has not attained its greatest de-"gree of perfection."

* see next page back

64.

t of P. T.

The Plane Table described by Francoeur in his "Géodésie," Paris, 1835, is almost identical with that of Benoît, and in fact the same may be said generally of those described by most writers upon the subject down to a very recent period. Among these authors may be mentioned Salneuve, ~~among the~~ French; Hartner, ~~among the~~ German~~s~~; Simms, ~~among the~~ English; - and Gillespie, Hackley, Davies, Loomis and others, ~~among the~~ American~~s~~.

In these short descriptions of the construction of the Plane

1 of D.T. Table, at successive periods, enough has been said to convey an idea of the various forms it has assumed, and the position it has occupied as a surveying instrument ~~among geodetic writers~~ from the time of its invention nearly to the present day. All the sources of information on the subject have not been exhausted, and to one interested in tracing the growth of instruments from their first rude inception to their adaptation to the more delicate and refined requirements of to-day, much is left for further investigation. But enough has been cited to show how slowly ~~the~~ improvements ~~of the instrument~~ have been adopted ~~appeared~~, and that the most important of them are comparatively ~~of~~ ~~quite~~ recent. ~~date~~.

76

g P.T.

[illegible] ~~[illegible]~~

why

[illegible]

we have found that [illegible]

from the [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] many writers from time [illegible] have been made [illegible] looked upon [illegible] affording [illegible] means for rapid and accurate

67

of P.T.

Topographical surveying [illegible] — It

that surveys

be reliable —— [illegible],

manipulation

[illegible] —,

[illegible] in their [illegible]

[illegible] this purpose [illegible]

intelligently employed.

And it is certainly never attainable

Through the appointment of topographers

1 in the hands of a skilful practical officer (2

the best [illegible] ✗ 3 [illegible] 2

3 and rapidity of work [illegible] in [illegible]

✱ 5 result to authority (n [illegible]

to represent the varied features [illegible]

natural accidents of the ground, — ✗

to found in such diversity [illegible]

coast of the United States ✱ (4 the as [illegible]

[illegible]) ~~in the hands of a~~

of P.T. ~~[illegible]~~ [illegible]

[illegible],

[illegible] ;-

[illegible];

[illegible]

[illegible];

[illegible]

[illegible]

[illegible], [illegible]

[illegible] for the [illegible]

[illegible]

[illegible]

delineation the establishing of the

of [illegible], [illegible]

neighbouring

~~[illegible]~~ [illegible]-

among the [illegible]

[illegible]

69.

t of P. T.

exhausted herself in the formation of a capricious and bewildering net-work of streams, ramifying the reed-grown swamps and treacherous quagmires in every direction;- in the thickly settled villages and among the rolling, farm-covered hills of New England;- on the broken, rocky shores of Maine,- the lofty ranges of California, with their volcanic cañons, wild and abrupt gorges and water worn barrancas;- or amidst the densely wooded mountains of Oregon and Washington;- on scales varying from the smallest which can safely be employed in the field, to that where minute distances are appreciable, the Plane Table has been

70.

~~on the whole~~

t of P. T.

employed with results, which ~~with those who have most used it~~, place its prëeminence beyond the field of discussion.

Dupain de Montesson, as quoted by Benoit, says:—"Ce n'est que "de gaieté de coeur, ou par ignorance, "que l'on donne un mauvais ou un "faux detail du pays en se servant "de la Planchette."

3.

Description
# of the
Plane Table.

[illegible]

presentation of [illegible]

[illegible]

[illegible]

the Plane table [illegible]

where are the [illegible] to the [illegible]

or in other words Topography is the repre-

sentation of the face of the country to a [illegible]

[illegible] of the [illegible]

of [illegible]

[illegible] Topographical [illegible]

drawn in pencil upon the paper which

is spread upon the Plane Table and then

[illegible] pencil [illegible]

[illegible]

2.

y P. T. [illegible] [illegible] [illegible] [illegible] as much the
that the operations [illegible] [illegible] [illegible]
be filled at once by the [illegible]
measurement and plotting of the [illegible]
and while it is done with as much
accuracy as it could be plotted with the
protractor [illegible] of transfer [illegible]
and much time saved.

The value of the Plane Table as a
topographical instrument having already
been stated, I will only give in re-
gard to the subject of this paper the
following remarks of Mr. Lee [illegible]
in his Practical and [illegible] [illegible].
"At the beginning of [illegible] [illegible] [illegible]
"is generally [illegible] [illegible]

3.

d of P.T.

"instruments for [illegible] [illegible]
"All operations are based [illegible] [illegible]
"results it follows that the [illegible] [illegible]
"operations and the accuracy of the [illegible]
"therefore will principally depend on the [illegible]
"exactness with which the instruments are
"made and handled and that these [illegible]
"we will advance in proportion as these
"are less difficult in their use and
"more perfect in the performance of their
"respective operations."

The Plane Table at present in
use [illegible] the first [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]

4.

t. of P. T.

[illegible] and have [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
commonly made of several pieces of wood
laid together and pressed together with
the grain running in different direc-
tions to prevent warping. To fit [illegible]
it when these [illegible] are used [illegible]
it is attached to [illegible] passing [illegible]
these and entering the [illegible] [illegible]
the board, the three holes for the inser-
tion of the screws being [illegible]
[illegible] [illegible] and [illegible] [illegible]
[illegible] from each other and from the
ends of the table. By means of these
screws the board can be removed at
will. The [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible]

5

r: q P. T.

[illegible]
[illegible]
[illegible] projecting from the
lower face of which, [illegible]
the [illegible]
with [illegible] corresponding [illegible]
somewhat greater diameter, project-
slightly beyond it. This [illegible]
forms the [illegible] and outer flange
[illegible] in the form of a
hollow cylinder. The inferior face
plane of the upper flange [illegible]
the contact with the [illegible]
the lower [illegible] orig
[illegible] common [illegible]
to the centre [illegible] of the [illegible]
[illegible]

6.

cr. of p. 4. held together by means of a circle [illegible]
axis of hard cylindrical [illegible] from the
centre of the inner face of the lower plate,
a socket of similar shape fits upon
[illegible] axis projecting downward from
the inner side of the apex of the [illegible]
or water line. The two plates are held
together by means of a milled [illegible]
screw entering the cone from the [illegible]
and which can be loosened or removed
at pleasure.

A tangent screw [illegible]
[illegible] fastened to the edge of the upper
one permits [illegible] the [illegible] to
be [illegible] about its centre [illegible]
[illegible] to the lower [illegible]
[illegible]

r. of P.T. the trumpet [illegible] [illegible] [illegible] [illegible]
movement [illegible] the end of the [illegible] [illegible]
pass through a small [illegible] [illegible]
of the other plate and the [illegible] [illegible]
through another plate [illegible] [illegible]
trunk [illegible] the [illegible] of the [illegible] [illegible]
The clamp is tightened by a simple
screw-lever.

Three epithelial sections
[illegible] of hard [illegible] on the [illegible]
side and set in one piece with the [illegible]
face of the [illegible] [illegible] [illegible] from [illegible]
[illegible] [illegible] the [illegible] [illegible] [illegible]
[illegible] of three [illegible] [illegible] [illegible]
through a [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]

8.

r° 9 P.T.

in place of [illegible] [illegible]. [illegible] [illegible] of [illegible] [illegible] in [illegible] [illegible] and 2 2/4 inches thick, and [illegible] [illegible].

The three several bolt [illegible] are [illegible] [illegible] [illegible] heads [illegible] [illegible] and [illegible] through the [illegible] [illegible] by means of [illegible] [illegible] [illegible] [illegible]. They are the [illegible] of [illegible] of the [illegible] [illegible] and [illegible] equivalent [illegible] [illegible] [illegible].

Upon the outer side [illegible] of the [illegible] metal [illegible] [illegible] [illegible] containing a [illegible] and a [illegible] which [illegible] through the [illegible] [illegible] from [illegible]. The [illegible] of the [illegible] [illegible] [illegible].

9

er. of P.T.

when the strap is [illegible] round the legs [illegible] both hands [illegible] [illegible] [illegible] at the [illegible] of the shoulders. This [illegible] cramped the whole upper part of the [illegible] instrument to the chest, and the [illegible] [illegible] before [illegible] — and kept [illegible] [illegible] at all other times.

The block [illegible] supported upon [illegible] left end with [illegible] from the [illegible] stand of the instrument, the left [illegible] with a length as to bring the [illegible] convenient height for working [illegible] be arranged as to be taken off [illegible] [illegible] at [illegible] [illegible] [illegible] [illegible] with [illegible] the [illegible] [illegible] [illegible] [illegible] [illegible]

10.

sec. of P.T.

[illegible]

11

cr.s of P.T.

[illegible] in such a way as never [illegible] not interfere with the working [illegible] of the Table.

A pair of compass sights or a small telescope called [illegible] [illegible] have [illegible] been attached to the side of the box of the Plane Table. When the Table has been put in position, the telescope is directed to some well [illegible] object, and by after reference to it any movement which may have taken place out of position in the Table during the use can be detected and corrected. This process is [illegible] by the [illegible]

[illegible]

Descr. of P. T.

[illegible] of the substitute stand. The which telescope has been [illegible] in "Coast" Survey work.

Rollers have been attached to the inside [illegible] of [illegible] These taking the place of [illegible] for holding the [illegible] but these are complications [illegible] to get out of order and are not regarded with favor by the [illegible]

The altitude is changed on instrument [illegible] by means of which a

13.

r. c P.T. [illegible] of [illegible] [illegible] [illegible] to [illegible]
a thermometer in [illegible] [illegible]
divided in one plane perpendicular
another in the north or south [illegible]
placed which upon a horizontal [illegible]
[illegible] the telescope with [illegible]
number of wires [illegible] directed [illegible]
same vertical plane.

A middle of a [illegible]
about 22 inches long having [illegible]
bent on the upper base [illegible]
of the tube [illegible] a perpendicular [illegible]
and column of [illegible] [illegible] the [illegible]
surmounted by two [illegible] plates [illegible]
by screws and supporting [illegible]
in [illegible] [illegible] placed [illegible]
[illegible]

14.

r^t of P.V.

[illegible] [illegible] [illegible] [illegible] frame and attached to the side of the stroke. This one [illegible] the [illegible] vertical movement of the telescope [illegible] [illegible] at the [illegible] by a [illegible] holds it in its place.

The telescope staff has the usual cross-hairs and means of focal adjustment.

A standard [illegible] is [illegible] to the edge of the upper [illegible] [illegible] at the top of the standard by means of adjusting screws.

The telescope is so placed that the line of collimation is [illegible] in the same vertical plane [illegible] [illegible] [illegible].

r^d of P.T.

A vertical ring, with a [illegible]

attached to the [illegible]

read with a vernier which [illegible]

telescope is raised or depressed [illegible]

measurement of vertical angles for [illegible]

small strip of brass is sometimes attached [illegible]

means of horizontal hinges to the edge of [illegible]

the purpose of lightening the vertical [illegible]

the trouble & the [illegible]

of obviating the necessity of watching the [illegible]

of the edge & the rule with the point [illegible]

as it is liable to the same objection as that

it has not come into general use. The former [illegible]

vernier of the altitude was fastened [illegible]

a hinge so that it could be let down [illegible]

rule for convenience of packing, but [illegible]

[illegible]

[illegible]

16.

r.s of P.T. [illegible]

[illegible] a [illegible] [illegible]

edge of the top; a scale of [illegible]

of brass or German silver, a [illegible]

clamps for fastening the map on the

Table, a box of Sharp pencils, india

rubber pencils and a hair brush [illegible]

the list of essentials for [illegible]

Plane Table work.

4.

Adjustments.

1.

justments

As in all other branches of geodesy, topography cannot be correctly executed unless the instrument is in proper order for the purpose, for however slight may be the disarrangement, error to a greater or less degree is sure to be the result of its use.-

When the Plane Table is furnished to the Chief of party at the beginning of a season it is supposed to be fit in every respect for the commencement of work, but it should nevertheless be his first duty to see if this be the case, for even if found correct the knowledge of the fact affords a satisfaction which amply repays the slight trouble of an

justments. [illegible]

From the nature of the device in some sections of country the Plane Table is often necessarily subjected to rough usage and there is a consequent liability to a disturbance of the adjustments; still in careful hands a well made instrument may be used under very unfavorable conditions for a long time without being perceptibly affected. One should not fail however to make occasional examinations and while at work if any difficulty be experienced which cannot otherwise be accounted for it should lead directly [illegible] [illegible] section.

Adjustments

The Adjustments. Before [illegible]
with the [illegible]
its adjustments carefully [illegible]
the instrument should be [illegible]

Adjustments of the Alidade

1. The fiducial edge of the rule.
This should be a true straight
line.

ajustments

First it will [illegible] [illegible], [illegible] and draw a line along the [illegible] [illegible] ing also the line at the ends of the tube. Reverse the rule [illegible] "straight" edge where the [illegible] "points" and again draw the line. If the two lines coincide no adjustment is necessary; if not the error [illegible] [illegible] made less by a careful [illegible] instrument maker.

There is one [illegible] ation from a straight line, which is [illegible] possible the edge of the straight [illegible] and yet not be [illegible] for there [illegible] when [illegible] [illegible] convex, and a perfectly [illegible] [illegible] [illegible] [illegible] [illegible]

5.

djustments. The same degree of [illegible] [illegible] one on [illegible] a line. In case of the [illegible] [illegible] test with the other [illegible] a true right line; but this is unlikely to occur, and it can be tested by an exact straight edge.

2. The level attached to the plane.
Place the instrument on the middle of the table and bring the bubble to the centre by means of the levelling screws of the table; draw lines along the end edges of the plate on the board, to show its exact position; then reverse.

djustments.

[illegible] [illegible] [illegible] [illegible] [illegible] centre [illegible] [illegible] [illegible] [illegible] correct it one half by the levelling screws of the base and the other half by the adjusting screws attached to the [illegible]. [illegible] [illegible] assertion until the bubble keeps its central position wherever [illegible] tele. may be turned upon [illegible]. This presupposes the plane of the [illegible] to be true.

If two levels are on [illegible] the other are examined and corrected in a like manner.

First one should [illegible] parallel in [illegible] [illegible]

7

ustments. [illegible] [illegible]

2. Parallax. [illegible] the [illegible] [illegible] on some distant [illegible] [illegible] and move the eye [illegible] [illegible] the [illegible]. If the [illegible] [illegible] [illegible] when the position of the eye is changed in some way, there is [illegible] [illegible] [illegible] [illegible] of the object glass must be moved until there is no displacement of [illegible]. When this is the case [illegible] [illegible] [illegible] in the common focus of the object and [illegible].—

justments. — To make the [illegible]
[illegible]
line of the telescope [illegible]
of collimation parallel to the [illegible]
to [illegible]. [illegible]
set up and [illegible]
cross-hairs [illegible]
other [illegible] of the cross-
hair [illegible] the [illegible]
[illegible] and [illegible],
the adjustments are perfect, and
[illegible]

9.

Adjustments

Transit [illegible] [illegible] [illegible] [illegible]
this error may be attributable to two
causes 1st the line of collimation is
not perpendicular to the horizontal axis
or 2nd the axis is not horizontal and
consequently not parallel to the plane
of the table. In the 1st point the
motion of the collimated line
curve and upon being moved to
the vertical line when the instrument is
horizontal will deviate from it
these points back upon elevation or
depression. In the second case the
movement of the cross hairs
in a straight line oblique to the
horizon [illegible] [illegible] [illegible]

[illegible]

djustments

[illegible]

Vertical [illegible] line of the vertical [illegible]

Then the instrument [illegible] the line of [illegible] stool:— [illegible]

[illegible] cal [illegible]

Adjustments.

[illegible]

[illegible]

Adjustments. [illegible]

[illegible]

"free" at the [illegible] of the [illegible]

[illegible]

the [illegible] to make it [illegible]

the [illegible] of the [illegible]

[illegible] that the [illegible] of the [illegible]

[illegible] between the

[illegible] of the [illegible]

[illegible] adjusted [illegible] the middle [illegible]

[illegible] will be in a place [illegible]

"free" or perpendicular to the [illegible]

axis.

After the [illegible]

horizontality of the [illegible]

[illegible]

13

djustments. The [illegible] [illegible]
[illegible] [illegible] [illegible]
the [illegible] [illegible] [illegible]
the effect of the [illegible] [illegible]
[illegible] [illegible] horizontal [illegible]
but the [illegible] is not [illegible]
one half of the correction [illegible]
corrected by means of the [illegible]
attaching the upper [illegible] (which [illegible]
the [illegible] of the horizontal [illegible])
top of the standard or by means of
[illegible] attaching the standard [illegible]
[illegible] The [illegible] attached [illegible]
[illegible] should then be made [illegible]

5. To make the line of collimation
parallel to the [illegible] [illegible]
[illegible]

Adjustments The [illegible] [illegible] of the [illegible] in most [illegible] [illegible] [illegible] essential that the [illegible] [illegible] remain constant. This [illegible] may be examined by means of needles stuck in the [illegible] & turned so that the needles [illegible] rectly to some distant object [illegible] side edge is placed against the [illegible] the telescope directed to the object & the cross-hairs bisect it the adjustment is correct, but if they do not [illegible] corrected by means of the screws attaching the standard to the [illegible]

0. Zero of the vertical [illegible].

13.

djustments. the vernier of the vertical arc should read 0° or the index error should be known. This may be examined by means of the distant sea horizon, or by setting up the alhidade so that the centre of the telescope is in the line of sight of an accurately adjusted levelling instrument, and then directing both instruments, while level, to a distant object; if any error be discovered it may be corrected by setting the vernier at 0° and adjusting the horizontal wire to the sea horizon or object.

When the above means are not available the following

djustments. [illegible]

[illegible]

of elevation or depression [illegible]

object [illegible] the instrument

that point [illegible] necessary

the [illegible]

the first and these angles should

be equal if the instrument be cor-

rect and if not equal the index

error will be one half the differ-

of the two readings.

A [illegible]

placed upon the [illegible]

[illegible] and [illegible]

[illegible] the [illegible] of the telescope [illegible]

[illegible]

[illegible]

justments.

[illegible] adjustments.

The preceding [illegible]

[illegible]

[illegible]

the points, XXVII [illegible]

[illegible]

Set up the [illegible]

[illegible] point.

[illegible] points [illegible]

say 100 or 150 metres apart. [illegible]

with the [illegible] the difference of [illegible]

of these two points [illegible]

Table & A. Measure carefully the

distance from the ground [illegible]

centre of the eye of the [illegible]

[illegible]

[illegible]

18.

justments.

the point B according as it is lower or higher than A. Set up a target or distinct point at this height at B, direct the cross-hairs upon it and correct the vernier accordingly.

Plane Table.

With regard to the Plane Table proper, a disturbance of its good working condition generally arises from accidents resulting from carelessness, or from undue exposure of the board to the inclemency of the weather, and where these injuries are of a serious nature, the mechanician only can apply the proper remedies.–

19

Adjustments of [illegible] [illegible]
expected [illegible] arrangement
[illegible] of the kind is to
be attempted in a very complete manner
but the main object in the [illegible]
is to be seen when the well
personal and facility in
instruction.

5.

Paper.

1.

aper.

I. Expansion and Contraction

[illegible] in the field, [illegible] and [illegible] accuracy of these [illegible] the errors which are [illegible] noted with the topographer [illegible] construction of the [illegible] causes, from the changes [illegible] from the [illegible] of temperature. The topographer [illegible] another element of error to contend with in the operations on the [illegible] of Paper, [illegible], which [illegible] unequally manufactured, is [illegible] affected by thermometric [illegible] [illegible] changes.

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2.

Paper.

From the experiments [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible], it [illegible] [illegible] [illegible] be considered for any great length [illegible] [illegible] [illegible] the relative proportions.

In order to [illegible] [illegible] [illegible] [illegible] to the [illegible] of the [illegible] [illegible] [illegible] [illegible] the [illegible] [illegible] [illegible] observations were [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] should be made [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

3.

Paper.

[illegible] of the [illegible] of the [illegible] to

[illegible] to

thermal alterations for the

strips of [illegible] by

[illegible] temperature [illegible]

the [illegible] strength of the

[illegible] and the [illegible]

[illegible] the [illegible]

[illegible] the [illegible] of

Mar 1862 to the end of Octo 1863,

with the average of temperature

32° to 95° and of [illegible] of

23° to 79° presenting the following

results.

4.

Paper.

[illegible]

[illegible]

[illegible]

	Lengthwise Strip.	Transverse Strip.
Mean expansion	76. mils	122 mils
" contraction	2.5 "	5.0 "
Maximum expansion	217.5 "	90.0 "
Minimum "	0.0 "	1.5 "
Maximum contraction	25.6 "	15.[illegible] "
Minimum "	19.2 "	.[illegible] "
Wet Bulb at max. expansion	65°	6[illegible]
" " " " contraction	62°	61°
Dry Bulb thermom. at max. expansion	69°	70°
" " " contraction	79°	79°
Mean Wet Bulb 63°		
" Dry Bulb 74°		

[illegible]

6.

Paper.

[illegible] to the alternation of [illegible] quality, [illegible] under the [illegible] of the above conditions, [illegible] immediately [illegible] gradually [illegible].

These [illegible] ed by [illegible] and [illegible] vegetation [illegible]

7.

Paper.

[illegible]

speaking, when a state of [illegible]

[illegible], it should be [illegible]

the [illegible], but the [illegible],

for obvious reasons, would [illegible]

[illegible], and it would [illegible] a

partial correction of [illegible]. In [illegible]

measurements of distance, they [illegible]

most [illegible] method of correction

to measure a [illegible]

at the [illegible] of [illegible], and [illegible]

[illegible] of all the [illegible]

that are the same, a [illegible]

with the [illegible],

and the amount of [illegible]

[illegible]

[illegible]

8.

Paper

[illegible] proportion [illegible] of [illegible]

[illegible] pen [illegible]

the various phenomena.

11. In the case of [illegible]

with pencil drawing paper, the [illegible]

[illegible] it would be well [illegible]

[illegible] lines, for a topographical [illegible]

previous to putting on the work, to

determine all the points, [illegible]

[illegible] found necessary for the

execution of the topography on the

[illegible] sheet, under the same

above process, there [illegible]

which the projection was [illegible]

[illegible] the [illegible] paper

[illegible], but [illegible]

[illegible]

9.

Paper.

[illegible]
[illegible] made [illegible]
[illegible] all the [illegible]
[illegible] therefore, [illegible]
communication with the [illegible]
[illegible] made, [illegible] of [illegible]
[illegible] fixed lines may be [illegible]
there is [illegible]
[illegible] for [illegible] and [illegible]
[illegible],
when the [illegible] are applied,
and that is by the system of
compensation [illegible]
action on [illegible] wire.

10.

Paper

II. Selection of Paper

The experiments [illegible] have been mentioned as having been made in the Coast Survey [illegible] mainly intended to ascertain the kind of Paper best adapted to [illegible] and among several varieties the stitched and backed antiquarian sheets now employed were found to be the best.

It is but comparatively recently that backing Paper with cotton cloth has been adopted in the Coast Survey, and it has been found that many advantages accrue from this [illegible].

11.

Paper.

The operation of stretching and mounting paper should be left to the office; but as circumstances may possibly occur where the Chief of Party would be obliged to prepare his own sheets, it is proper that the method to be employed should be given here.

The sheet should be sufficiently large to admit of the turning of a narrow edge all around. Lay a straight flat rule on the paper, and let it stand half an inch from the edge, hold the rule firmly and turn up the projecting edge of paper; this should be done on all of the four sides.

[illegible] the [illegible] after the

[illegible]

12.

Paper

board, [illegible]
then, with a sponge and [illegible],
clean water, damp it [illegible] and
thoroughly the whole surface, leaving
by the board one edge. When the
paper absorbs the water it may be
seen by the outside becoming dry
when looked at obliquely against
the light, it should be turned
on the board, with the wetted side
downwards, the edges being parallel
to the edges of the board. Cover the
turned up edge with glue and
press it down to the board with
the hand and then finally [illegible]
with the [illegible] of [illegible]
[illegible]

13.

Paper

[illegible] cemented to the board. Further each adjoining edge must be done in the same manner and so on in succession till all the remaining edges are glued fast to the board. When dry cut the Paper off by means of a sharp knife and a thin straight edge pressed well down upon the board.

The requirements of field parties call for more backed Paper than can be supplied by the use of a board or table and [illegible] frames [illegible] with [illegible] [illegible]

14.

Paper.

[illegible] the [illegible] would [illegible] of good [illegible] would perhaps be preferable. In either case the process is substantially the same.

Muslin [illegible] the size of any given sheet of paper is saturated with water, and after being well wrung out, it is tacked fast to one edge of the table, the [illegible] being taken [illegible] fastening it down to stretch the cloth in length as much as it will bear. The opposite edge is then pulled [illegible] by width and tacked down so to make the [illegible] even, as much as possible [illegible]

[illegible]

15

Paper.

the [illegible] [illegible] [illegible] [illegible] [illegible]
the [illegible] [illegible], and the [illegible] [illegible]
the leaves to [illegible] properly, the [illegible]
position [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] paper [illegible]
[illegible].

Considering the paper [illegible]
whatever kind it may be, [illegible]
[illegible] by the application of
[illegible] these parts of the [illegible]
quality. Some having [illegible]
[illegible] [illegible] [illegible] are [illegible] [illegible]
alteration, the [illegible] however [illegible]
somewhat dependent on atmospheric
condition. The test in this part
the process is a perceptible, [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

16.

Paper

the Paper. Upon that is spread the paste side of the paper [illegible] according to the [illegible] different [illegible] with the hand, care being taken to [illegible] even pressure any [illegible] between the muslin and the [illegible]. The drying should be gradual and when perfectly dry the [illegible] may be removed. The [illegible]

The following [illegible] a [illegible] should be made [illegible] to [illegible], in the [illegible]

17.

Paper

[illegible]
and then all [illegible]
the [illegible]
[illegible] each other [illegible]
of the [illegible]
which should be [illegible]
both ends. If done [illegible]
will give a neat and [illegible]
when they are [illegible] together. The
paste which should be used for this purpose,
and after being pressed [illegible]
be placed under a [illegible]
till dry. [illegible]
[illegible]
[illegible]

C.

Projections.

1.

rojections.

I Brief Account of Projections.

As the small amount of knowledge possessed by them of the habitable globe, rendering the latitudes and longitudes, particularly the latter, greatly erroneous, prevented its representation with any degree of precision, and as an indispensable element in the construction of maps, the determination of the circumference of the earth was sought by the most ancient astronomical geographers.

A clear conception of the globular form of the earth, first suggested by Thales, who was born

ojections.

640 B. C. did not immediately follow the theory which prevailed in the time of Homer, of a flat surface, supporting the heavens in the form of a dome like canopy; but when Eratosthenes, the founder of geodesy, began his labors of tracing the first parallel, the doctrine of its sphericity had, owing to the increase of astronomical knowledge and the improvements in the means of observation, become fully accepted. Although various attempts had probably been made previous to his time to ascertain the circumference of the earth, yet he was the first to attempt to delineate

3.

ojections.

by the application of comparatively correct methods those parts of its surface known to mankind. He supposed a line to be traced through certain places, in all of which the longest day was known to be of exactly the same length, which would of course, be parallel to the equator.

This system, founded upon the use of the *gnomon*, an upright pillar erected upon a prepared level space, by the measurement of whose meridian shadow the progress of the sun from tropic to tropic could be traced with tolerable correctness, - owing to the want

4.

Projections

of accurate observations, was rendered very uncertain in practice.–

The parallel drawn on this basis was supposed to reach the entire circuit of the earth; but was, in fact but little more than one third its length, and extended through the middle of the Mediterranean.– Other parallels at specified intervals from the first were then traced, and also a meridian at right angles to them.–

This was succeeded by a further endeavor to measure the circumference of the earth.– The celestial arc between the two zeniths of Syene in Upper Egypt

5.

ojections.

and Alexandria, supposed to be on the same meridian, and bearing the same relation to the celestial great circle as the distance between the two places on the surface of the earth bore to its circumference, was measured, and from this was its value computed. From a combination of errors, however, in estimate of distances, inadequacy of instruments and inaccuracy of observations and deductions, the result came but little nearer the truth, being still nearly two thirds too small.

The great astronomer Hipparchus, who flourished between

ojections

160 and 135 B. C. was the first who undertook the laborious task of forming a catalogue of the stars, and fixing their relative positions by means of an imaginary celestial equator and poles, and of applying the same principle to the determination of points on the earth. He was also the first to determine the longitudes of places, by means of observations of the eclipses. of the sun and moon, and, having made a considerable number of observations for latitude, was enable to produce maps upon which, for the first time, localities were designated by these means. A due

7.
rojections

estimate however, of the importance of this advance in geographical science does not seem to have been made till the astronomer and geographer Ptolemy prepared his very complete map, as far as the world was then known, on these principles; for the leading intermediate authors, such as Strabo and Pliny give the positions of places by the gnomon only, and are silent on the subject of latitude and longitude.

The most ancient maps of which we have any account are those of Seostris, which appear to have been mere records of his

8.

rojections

marches, and the first Grecian map on record is that of Anaximander, mentioned by Strabo. An idea, however, of the character of these early productions is best obtained from that of Aristagorus, King of Miletus, as described by Herodotus, which, as a map of the world, contained little more than the states of Greece and the digested surveys of the marches of Alexander. The errors of distances were sometimes enormous, and with the exception of that of Eratosthenes, the maps had hitherto, down to the time when the true principles of geography had been pointed out by

9.
ojections

Hipparchus in the application of latitude and longitude to places on the earth, been little more than the rudest general outlines of great states and as rude topographical sketches of special countries. The most ancient maps which have reached modern times are those illustrating the geography of Ptolemy, and which gave the positions of places after the principles laid down by Hipparchus, by their latitudes and longitudes, and upon which the meridians were made to approach each other towards the poles, giving several plans of the sphere in approximation to the

10.

ojections

stereographic theory.

—Although this map continued for many centuries to be the great geographical authority, yet, from the inaccurate measurement of the length of a degree, the precision aimed at was very far from being reached. It was found that the results of the only observations employed by the ancients, those of the eclipses of the moon, could not be relied on, and it was not till 1610 that the observations of the eclipses of the Satellites of Jupiter, discovered by Galileo, were, at his suggestion, adopted. This however was employed to but little purpose

11.

rojections.

till 1668, when Cassin prepared his tables. Shortly afterwards by means of simultaneous observations by himself and Picard at Paris, and Tycho Brahé at Copenhagen, the difference of longitude of these two points was finally determined.

In the meantime scientific men had not been idle in investigating another important question upon the solution of which the exact delineation of maps depends, — that of the figure of the earth. —

In the 9th century an attempt was made by mathematicians under Al Mamun, Caliph of Bagdad, to determine the length of

12.

Projections

a degree of latitude, in which they agreed with Ptolemy, probably adopting, instead of verifying his conclusions. Nothing was now done in this direction till about the middle of the 16th century, when the French physician Fernel measured the distance between Paris and Amiens by the number of revolutions of his carriage wheel and by observations for latitude, producing a remarkably close approximation to the length of a line connecting those two places. Willebrord Snell, who was the first to apply triangulation to this purpose, for which he used a large quadrant, measured the distance

13.

Projections.

between Alkmaar and Bergen-op-Zoom in 1617, and in 1635 Norwood repeated the operation in England, employing the road between London and York.

In the same year the difference of longitude between Marseilles and Aleppo was found to be no less than 15° less than that laid down on the map, and the necessity for more perfect observations became apparent. As constant improvements were being made in the construction of instruments, however, and in the use of them and the application of the results obtained, means were arrived at towards the end of the century whereby maps could be con-

ojections.

structed with far greater accuracy than any hitherto published.

A new map of the world, as well as of Europe, Asia and Africa, founded upon comparatively accurate astronomical data, and in which the errors derived from the maps of the ancients were first corrected, was published by De Lisle in 1700, and this may be considered the starting point of the true system of map making. From the beginning of the 18th century, then, may be said to date the system of Projections, or at least, the correct application of a system which had been used in a partial and inaccurate

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Projections

manner only, previous to this time, and it is hardly worth while to trace from this comparatively recent period the progress made in obtaining results necessary for the production of accurate maps, nor the different methods employed in applying them.

A history of maps and their construction from the first rude, grossly inaccurate attempts of the earliest times, when the countries were represented by coarse and distorted perspective, and the climates vaguely shadowed forth by roughly executed figures of men, vegetation and animals, down to the present day when a point of accuracy and finish of

16.

Projections.

execution has been reached which appears to be limited only by causes of a purely physical nature, is a subject of much interest, but does not come within the province of this article.

We have thus given in a very brief outline from the earliest period of which we have any record down to a time when the correct principle may be said to have been reached and established, the prominent points of the progress of the determinations of latitudes and longitudes and the figure of the earth, as affording an idea of the growth of the system upon which all maps are laid down, for upon the correct-

17.

Projections

ness of these three essentials the correctness of the map which is founded upon them chiefly depends.

II Projections.

Strictly speaking the best representation of the earth or of any section of its surface would be that formed upon a spheroidal body, or one of the shape of the earth itself; but the manifest difficulty of the construction and transportation of globes, or parts of globes and the inconvenience of their use, save to a limited extent and only when of

18.

Projections

very small dimensions, has led to the necessity of their representation upon plane surfaces.–

To this end descriptive geometry, a useful and fruitful branch of mathematics, which forms the basis of the science of the engineer and the surveyor, through the application of the laws of graphic design, affords us the means of the practical employment of the method of representation of the figure of the earth or parts of the earth, upon a plane surface, known as the system of Projections.

When a single plane of reference, embracing any required number of points of a surface which it

19.

Projections.

is desired to represent upon it, is connected by means of imaginary perpendicular lines drawn by shortest distances from the points of the surface to the plane itself, thus giving on the plane the correct relative positions of these points, it is called the plane of Projection, the shortest distances or lines ordinates and their extremities upon the plane of Projection, projected points. By showing upon the plane of Projection the positions of all the points respectively to each other which form the surface of a certain area of ground in the simplest and clearest manner possible, we give the most exact description of it both

20.

ojections.

as to form and dimensions. The figure resulting, usually smaller than that which it represents, is called the plan, chart, or map. In other words a truly correct map of a certain surface or area of ground is the Projection of an infinite number of points of that surface, and embracing all its parts upon a plane of Projection. - So that the graphic description of a body is reduced to:- 1st. the Projections of all the points of its surface upon a plane of Projection, and 2nd. the true lengths of the corresponding ordinates;- the first giving the plan and the second the differences of elevation. In the construction of charts,

21.

Projections.

however, this theory of graphic design is susceptible of only a limited degree of exactness and application without the assistance of trigonometry and algebraic analysis. Astronomy, as we have seen, furnishes us with the position, direction and extent of the lines of parallel and meridian, and trigonometry gives the location, respecting these lines, of certain points upon the surface of the earth, and descriptive geometry the means of combining them upon the paper, - and this sheet forms the Projection upon which, in filling in the details of the country embraced within its area, the labors of the topographer

Projections. are expended.

Different systems or methods have been invented, by which, in this convenient form of plane sheets the true delineations of the surface of the earth may be presented; - and these systems have differed according to the supposed position of the eye, or an assumed point in space.

If we conceive a series of straight lines carried from the eye to all the points of the surface of the earth, considered as spherical, and cut this system by a plane placed in any position, all the points of incidence on this plane,

23.

Projections. will, as we have seen, form the Projections of the corresponding points on the surface of the globe.

1st When the eye is assumed to be at one of the poles it is called a Polar or Equatorial Projection.

2nd When it is on the equator it is called Meridional.

3rd When it is between the pole and the equator, Horizontal.

4th When it is at the centre of the earth, Gnomic or Central.

5th When it is at a distance from the sphere equal to the sine of 45°, Globular.—

These divisions are called by the general name of Stenographic

Projections.

Projections and are employed to represent an entire hemisphere or large portions of it, the surface to be delineated being usually the opposite hemisphere, of which the inner or concave side is presented to the eye, and the positions of the most remarkable places only of the globe are indicated.

For the purpose of representing a smaller extent of country, by means of chorographic charts, embracing small states, or topographical maps which furnish all the details of the ground, Orthographic Projections are employed. These are constructed upon the prin-

25.

Projections. ciple of supposing the eye to be at an infinite distance from the earth, so that the lines carried from it may be considered as parallel to each other. If this series of lines and their Projections, instead of including all the points upon the surface of the earth are confined solely to the parallels and meridians and points of triangulation, and the plane of Projection is a sheet of paper of certain desired limits, this sheet of paper forms the Projection of the topographer.

Among curved surfaces, those of cylinders and cones are developable, that is to say, may be extended on a plane without duplicature,

26.

Projections. which is not the case with the sphere, and for topographical purposes in the Coast Survey, the system of orthographic Projections is applied according to the principles of the development of the cone, and for this reason the Projections are called Conic or Polyconic. In this method, which originated with the English Astronomer Royal Flamsteed, and which was introduced into the Coast Survey by Superintendent Hassler, the portion of the sphere to be represented is regarded as coincident with a portion of a cone touching the sphere in a circle either "tangent to a certain latitude or cutting two given

27.

Projections "parallels and two meridians equidistant "from the middle meridian, and extended "on both sides of the meridian, "and in latitude only so far as to "admit of no deviation from the "real magnitudes such as would be "sensible in the detail surveys." This portion of the cone when developed on the plane of Projection in the sector of a circle gives the meridians as straight lines converging toward the vertex, or the pole, which is the centre of the sector, - and the parallels as arcs of circle have for a common centre the same vertex, being on account of equal graduations in latitude, equidistant. In

Projections.

this system "the radii of curvature of "the parallels and meridians depending "upon the value given to the expression "for the ellipticity and the assumed "form of the globe are important terms. "For practical use tables have been "computed in the office of the Coast "Survey showing the length in metres "of every minute and second of the "arcs of the meridians and parallels "comprehended in the maps."

The "determined points" of a scheme of triangulation are the vertices of triangles whose geographical positions have been obtained by observations in the field, and these are plotted by means of

29.

Projections.

data giving their distances from each other as well as their positions, in minutes and seconds reduced to metres, as above mentioned, which data are known under the name of "L. M. Z's."

"It has been found necessary to recalculate the tables since "1844 on account of the new value "of the ellipticity announced by "Bessel and adopted by the present "Superintendent." "The tables for computing the triangles have also been "affected by this change, and the "formulae have been revised, and, "undoubtedly greatly improved in "convenience and accuracy. The

30.

rojections. "tables have undergone a further modification by substituting the legal "rates of the metre to the toise, in "place of the arbitrary standard resulting from the ingenious, but (as "Bessel has said) 'not allowable' "comparisons of Mr. Hassler."

In the excellent system of the division of labor upon which the Coast Survey is conducted, as the duties of the triangulator commence where those of the astronomer cease, so do the labors of the topographer follow those of the triangulator, and it is upon the data furnished by the latter that the

31.

Projections.

work of the topographer is founded. As already stated, it is from these data that the Projection upon which the topography is executed is made, and though it is customary for the sheets destined to be used by the topographical parties in the field to be prepared at the office, contingencies frequently arise when it is found necessary for the Chief of party or his Aid to make his own Projections, and as a guide for that purpose the following directions are given, it being well to remember that delicacy of manipulation is an important element in the avoidance of error.

Projections

II [illegible]

[illegible]

2nd [illegible]

3rd [illegible]

[illegible]

33.

Projections.

ance of the sheet when finished.

It is presumed that a map or sketch has been furnished giving the positions of the determined points and the approximate outline of the country, so that the general configuration of the shores and ground is shown. The limits of the sheet then having been determined the middle meridian (A) (see Diagram no 1.) is located and drawn, and the intersection upon it of the most nearly central parallel determined, at which point a right line (B) should be erected perpendicular to the meridian (A) transversing the sheet and representing the central parallel.—

jections

[illegible]

35.

Projections. the extremes of the line representing the central parallel. With a well tested straight edge draw lines (E. E) through the extreme North and South minutes on the central meridian and tangent to the two arcs (D. D) to the right and left as described above. This gives three parallel lines (E E. B B, & E E.) representing the central and extreme North and South parallels, intersected perpendicularly by the central meridian. Ascertain how many minutes of longitude are embraced East and West of the central meridian and lay off the whole distance (F. F.' F.") on each parallel on either side each to be taken at its corresponding lati-

Projections.

tude from the tables under the head of "Lengths of arcs of parallel." Subdivide these into minutes (G. G.' G.")

For the areas usually covered by field sheets, the abscissas "X," under the head of "Co-ordinates of Curvature," are inappreciable and can be disregarded, the ordinates under the head of "Y" only being used. These measures of curvature give the distances to be set off towards the pole and perpendicular to the parallels, for each minute of longitude, counting from the central meridian. For ordinary field Projections scale $\frac{1}{10.000}$ the ordinate of the extreme minute need only be used and the

37.

Projections.

parallel drawn as a right line from the point so formed to the central meridian. This ordinate (H) being set off on each parallel, the meridians are all drawn in black ink with a fine ruling pen, subdivided into minutes and parallels carefully ruled in ink through the points of subdivision of the meridians.

The Projection is verified by applying the measure of a number of minutes of latitude and longitude, and by a comparison of diagonal measurements on different parts of the sheet.

All measurements should be accurately taken from the scale

Projections.

with a keenly pointed beam compass, and the marks pricked in the paper should be as light as possible to be visible, in order to insure the greatest possible precision.

The triangulation points are each plotted by coördinates, which are furnished in metres, for seconds and parts of seconds, with the "L. M. Z's" already referred to. The origin of the coördinates is in the South East angle of the minute within which the point falls. "D. M" is the distance on the meridian (J) or north from this angle, and "D P" is the distance on the parallel west (K) from the point thus found by the

30.

rojections

In the [illegible] to the [illegible]
[illegible] is [illegible] given [illegible]
[illegible] and [illegible] of [illegible]
[illegible] which include the [illegible]
these points are connected by a [illegible]
[illegible] line, and on that line the
[illegible] is dotted.

The accuracy of the
dotting is tested by a [illegible]
the respective distances between the
points with the same [illegible]
[illegible] being also given in the [illegible]
The degrees and minutes are [illegible]
of [illegible]
[illegible] of the [illegible]
and parallel and [illegible]
[illegible]

Projections. [illegible]

It sometimes becomes necessary [illegible]
in Topographical work [illegible]
[illegible]
astronomical observations [illegible]
made [illegible]
[illegible]
to two principal types of [illegible]
[illegible] ([illegible]) [illegible]
[illegible]
70. The [illegible]
[illegible]
[illegible]
[illegible]

Projection.

the points thus given [illegible]
for plotting these curves [illegible]
right of X axis (as drawn in the [illegible]
but it will be seen that the general
appearance of the curves will be the
same. Most convenient for rough work,
when the points are plotted given [illegible]
by the intersection of two circles [illegible]
distances furnished of the points [illegible]
to use as rating [illegible] [illegible]
test in test of the lines of [illegible]
+ or − signs given these [illegible]
only test is by the distances between
the points and lines should [illegible]
test [illegible] how each [illegible]
[illegible]
[illegible]

Projections

[illegible]

[illegible]

[illegible]

Projections.

[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] the [illegible] [illegible]
[illegible] [illegible] the [illegible] [illegible]
of a [illegible] [illegible] [illegible].

The projection is [illegible]
[illegible] upon which the [illegible] [illegible]
is of the [illegible] [illegible] [illegible]
[illegible] in the [illegible] of the [illegible]
[illegible] and the [illegible] [illegible] [illegible]
work [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] for [illegible] purposes [illegible]
otherwise.

7.

Measures.

1

Measures.

It is not intended, nor, indeed is it necessary to give, as a part of this paper, a detailed account of the history of metrology. The subject has been fully treated of in works which are easily accessible, and it is one which would fill many papers far more voluminous than can be afforded, or are needed here; - but it is thought that by the beginner, who has paid the matter but little if any serious attention, and who is to be in daily use of them, ~~that~~ a brief statement of the nature of the Measures which he is to employ will not be deemed super-

2.

asures.

fluous. As the whole subject is now receiving so much elucidation in consequence of the legalization and gradual introduction of the French metrical system into the various branches of trade, commerce and scientific professions of the United States, the few words which are given to it are purposely merely elementary, and designed only to serve as general information for the young topographical student. It is considered that the topographer, in order to work intelligently, should be possessed of some knowledge beyond the mere mechanical use of

3

easures.

the means furnished him for his labors in the field. To this end, also, are written the preliminary observations of the articles upon projections and scales.—

All Measures of whatever kind are composed of sums or fractions of some unit of standard value, and upon the fixedness and accuracy of this element the values of those referable to it depend, and to secure uniformity, simplicity and the least possible variability in this standard is a problem which has taxed scientific in-

4.

Measures.

genuity for a long series of years, and upon which a vast amount of scientific research and refinement of methods have been expended.

As far back as the history of measurements leads us, we find that they had their origin in the lengths or widths of portions of the human body,- and among those of different countries are found such arbitrary standards as the fingers' length and breadth,- the digit, or second joint of the forefinger, the nail, palm, span, cubit or length of forearm, orgia or stretch of arms, foot, pace, hairbreadth, ect, ect.-

5.

Measures

Some of these designations, as the English foot, and the French *pouce* or thumb for the inch are yet in use and the Arabs are still said to employ the forearm as their cubit Measure of cloth.—

The inadequacy of such uncertain and unstable primary lengths to convey definite and accurate notions of Measures derived from or founded upon them, was felt at an early day in the perplexing hinderance to commercial intercourse, in their application to itinerary Measures, or in the estimation of their extended distances where a want of agreement in fun-

6.

Measures.

damental lengths, which may have been unimportant when but few were considered, but which, in repeated multiplication, would result in very great discrepances. These differences, in the progress of mankind toward exactness, led, among the Greeks and Romans, to the establishment of a conventional average of the measurements of different nations;- but even this, though an amelioration, did not satisfactorily remedy the trouble.- Various methods were essayed for arriving at a satisfactory result; but for a long period even down to a late day, with but partial

7

Measures.

success.—

In 1324 the statute of Edward II of England provides that the length of three round and dry "barley corns" should make an inch, and 12 inches the foot, and so on; but it is apparent that this unit was but little more definite, or less crude and irregular than the adoption of the foot of Louis XIV. in France.

Repeated changes of the elemental unit among the different nations of Europe, however, continued to result in unavoidable confusion in the comparisons of their different measurements, and

8.

easures.

the attempts to overcome these difficulties brought about the institution of careful and accurate comparisons of each given kind of standard in a country, to ascertain which most accurately maintained the Measure originally adopted, and to select one which should be reliable and which could be multiplied and perpetuated. – Accordingly, in 1736, under the auspices of the Royal Society of England a comparison of the English, French and old Roman standards was made.

Until about forty years ago the standards of weight and Measure in England were most

9.
Measures.

irregular. The standard length was a metal yard which had been in the custody of the Clerk of the House of Commons since 1760. But many of these inequalities were removed by an act of Parliament passed in 1824. The old yard, by this enactment, is retained as the standard of length, and in order to verify it in case of destruction a ratio was established between its length and the length of a pendulum. It was found that a pendulum vibrating seconds in the latitude of London measured 39.1393 of such inches as are marked on this standard yard, and the standard

10.

Measures. yard of England is defined by act
of Parliament, as "that distance between
" the centres of the two points
" in gold studs in the straight brass
" rod now in the custody of the clerk
" of the House of Commons, wherever
" the words and figures "Standard
" yard 1760" are engraved, which is
" declared to be the genuine standard
" of the measure of length called
" a yard." As the oscillations of the
pendulum, however, vary in different
latitudes, and the lengths of the
rods are affected by the expansibility
of the metal under the
changes of temperature, - the yard,
after all is at best an arbitrary

11.

Measures.

unit of the Measure, and it still remained for some body of scientific men to endeavor to establish or ascertain, from among the fixed objects of nature, a standard clearly definite and unvarying from any cause or combination of causes, and accessible to all mankind, and which, with the most refined application of scientific laws, could be made to serve this most useful and long needed purpose.–

To the French savans of the period of the Revolution belongs the credit of measurably effecting this object, and the establishment of a metrical system as

12.

Measures. nearly perfect as the present state of science, and human ingenuity and minuteness of investigation can furnish.—

The distance in a terrestrial arc between the equator and the pole is a constant quantity and any assigned part of that distance invariable, and affords an unalterable reference for Measures adapted to all purposes of exact metrology. Upon the measurement of this quadrant of a meridian the French system is founded, and by a decree of the National Assembly the _metre_, or an aliquot part of the terrestrial meridian,

15.

Answers: the unit of length, capacity, or weight, should be the ten millionth part of this quadrant, and the sub-divisions and multiples in the system follow in decimal progression, the sub-divisions of linear measure being designated by the Latin decimal prefixes *deci* = $\frac{1}{10}$; *centi* = $\frac{1}{100}$; *milli* = $\frac{1}{1000}$; and the multiples by the Greek decimal prefixes of *hecto* = 100; *kilo* = 1000; *myria* = 10.000. It follows, therefore, that the earth, supposing it to be spherical, is forty millions of metres in circumference and has a radius of 6366.198 metres, or, for most practical geo-

14.

Measures.

detic purposes, allowing for want of sphericity, the mean radius may be taken at 6375,110 metres.

In M. Delambre and Mechain, two distinguished mathematicians, commenced in 1792 the great trigonometrical measurement of an arc of the meridian extending from Dunkirk, in France, to Barcelona in Spain, and completed their work in   . In 1806 the triangulation was extended from Barcelona through Spain to the coast of the Mediterranean; and subsequently, after the death of Mechain, who fell a victim to his exertions, by Biot and

13.

Measures.

Arago to the Balearic Isles. The whole, thus extended from Dunkirk, on the north, to Formentara on the south, comprehends 12°. 22′. Cassini and Lacaille had previously measured a smaller arc in 1739; but it is from the former that the standard of the metre, as at present used, is taken. Before the completion of this measurement, however, it was deemed necessary to employ a "provisional metre" corresponding with surveys already made, and introduced in 1795.

It was not till the 19th Frimaire year VIII (10th Dec. 1799) that the legal metre of France was

16.

Measures.

established. It was ordained that it should be fixed at 443,296 lines of the toise of Peru in iron, at 13° Reaumur, or 16¼° centigrades of the mercurial thermometer, or 32° Fahrenheit, the temperature of melting ice.

An aversion however, on the part of the French people to this new innovation, as it was considered, induced, in 1812, the ingrafting upon the metrical system of the binary or systême usuel, a species of compromise, adopting the new standards; but the divisions corresponding nearly with those heretofore employed,

17

Measures.

rising generally in ratios of 2, 3, 8, or 12. This method was abolished in 1837, however, and after a struggle which had already been protracted through a series of years against old prejudices and habits and various political and commercial obstacles, the establishment of the metre and its derivatives was finally adopted, in France in 1840, to take effect after the 1st of January. Since that period the system has rapidly advanced in favor, not only in that country, but among scientific men of all other nations, and its use is now authorized

18.

Measures.

by act of Congress in the United States.

Thus one common unit, based on a subdivision of the earth's surface, furnishes a key to the size and capacity of all the metrical weights and Measures; but this fact would not prove a very good reason for the proposed change, were it not accompanied by a system by which each of the units mentioned above is divided decimally, and larger units formed by multiples of ten, one hundred, &c.

It has already been ascertained that the measurement of the meridian, on which the metre

19.

easures.

is founded, is, by a minute fraction too small; in other words, that the whole circumference determined is slightly over 40.000.000 metres in length. According to Bessel the distance from the equator to the pole, thus established is 935 yards too small, according to Puissant 1,410, and according to Chazallon 1,967. The metre is not then, strickly speaking, the ten millionth part of the quarter of a meridian; but the difference is so minute as not to be appreciable in ordinary geodetic work; but from the fact that the artificial standard can not, without a labor which ran

10

Measures.

through a course of years, and which could hardly be expected would be again undertaken, be corrected by a recurrence to the standard in nature, the metre itself becomes in fact no less arbitrary than the yard or foot. Its chief value rests, therefore, upon the beautiful and simple system which is founded upon it, and upon that chiefly does its claim to superiority rest.

The metre is marked by two very fine parallel lines drawn on a bar of platinum and preserved in the archives, of the Academy of Sciences in Paris.

In a scientific point of

21.

Measures

view no system of metrology hitherto devised can compare with this of the French and the following gives the multiples and divisions as established.

Myriametre —	10.000.	metres
Kilometre —	1 000.	"
Hectometre —	100.	"
Metre —	1.	"
Decimetre —	0.1	"
Centimetre —	0.01	"
Millimetre —	0.001	"

And the following gives these values in standard English inches the metre being taken at 32° and the foot at 62°.

Millimetre = .03937

Centimetre = .39371

Decimetre = 3.93710

Metre = 39.37100

Decametre = 393.71000

Hectometre = 3937.10000

Kilometre = 39371.00000

Myriametre = 393710.00000

This represents Kater's value; Baily more reliably gives 39.37009 as the value of the metre in inches, but the standard of the Coast Survey which was supposed to be identical with those used in the above comparisons gives 39.36850. These differences are mainly questions of the expansion by temperature of particular pieces

23

asures.

of metal, since you cannot well compare a metre at 32° with a yard at 62°; 39.3700 inches is as near however as under the present stage of information it is worth while to go, $\frac{1}{10.000}$ of an inch is an exceedingly small quantity. In all horizontal measurements in the Coast Survey the French metre is employed and in the calculation of heights the English foot is used. Appended are tables which may at times be found serviceable for reducing metres to feet, yards, and rods and *vice versa*, also the values in metres of the English nautical and statute miles.

14.

Measures.

With regard to the relation of the yard to the metre, a very convenient set of factors, easily remembered, and quite accurate when ordinary variations of temperature are thrown in, is

$$1\text{ yard} = \frac{4 \times 8}{5 \times 7}\text{ metre}.-$$

Table.

Measures.

For reducing Metres to Feet, Yards & Rods.

Metres	Feet.	Yards.	Rods.
1	3.281	1.094	0.199
2	6.561	2.187	0.398
3	9.842	3.281	0.596
4	13.123	4.374	0.795
5	16.403	5.468	0.994
10	32.807	10.936	1.988
20	65.614	21.871	3.977
40	131.228	43.743	7.953
50	164.035	54.678	9.942
100	328.071	109.357	19.883
500	1640.354	546.785	99.415
1000	3280.709	1093.570	198.831

For reducing Feet, Yards, & Rods to Metres.

Feet	Metres	Yards	Metres	Rods	Metres.
1	0.305	1	0.914	1	5.029
2	0.610	2	1.829	2	10.059
3	0.914	3	2.743	3	15.088
4	1.219	4	3.658	4	20.118
5	1.524	5	4.572	5	25.147
10	3.048	10	9.144	10	50.294
20	6.096	20	18.289	20	100.588
40	12.192	40	36.577	40	201.176
50	15.241	50	45.722	50	251.470
100	30.481	100	91.444	100	502.940
500	152.406	500	457.218	500	2514.700
1000	304.812	1000	914.437	1000	5029.400

1 naut.l mile = 1855.110 metres
1 St. " = 1609.408 "

I.

Scales.

19.

Scales. take from off the Scale 627 metres, to be transferred to the map:- Place one foot of the dividers on the 6th perpendicular from the diagonal Scale, and the other foot at the bottom of the 3rd diagonal line, then run both feet of the dividers up on these two lines to the line above the 7th horizontal space, and the distance is found. A very little practice will enable one to take off these distances directly and with rapidity.

The theory upon which the diagonal Scale is constructed is so simple and evident that it is not thought worth while to give it here.

1.

Scales.

I Scales.

As has been stated in the preceding paper descriptive geometry affords the means of placing upon a sheet of paper an indefinite number of points in positions respectively similar to those of any surface which these points are intended to represent, and this serves as the basis of the method employed in obtaining a geometric figure similar to a natural topographical area of ground. This figure will always give a correct idea of the respective positions of objects as well as of their relative distances from each other; but we can

2

Scales.

determine nothing of the relation of the distances and extent of the objects upon the paper to the real distances and extent of the objects in nature, unless we know how many times the distance between any two points on the chart is contained in the distance it represents. The latter should be known and expressed in the same units of measure as the former, and the two numbers, which are furnished by the two measures, will give a fraction, which, being reduced so as to have a unit for numerator, will give the relation required; or, in other words, the Scale of the chart.

As the size of the topo-

3.

Scales.

graphical plan can be drawn in any proportion whatever to that of the tract represented, the number of the Scales is unlimited, and it is therefore necessary to choose those which present the greatest convenience for work, and which give the readiest expression of this mutual relation. Those which afford this are the decimal Scales adopted by the Commission of Public Service in France, convoked in the year II of the revolution to determine, among other matters, the Scales best suited to the plans of maps which that service required, and best in harmony with the existing system of enumeration.

4

[illegible]

[illegible]

system are divided [illegible]

according to [illegible] of the [illegible]

a denominator which [illegible]

[illegible] of 2005 at 2000 [illegible] 2000

2000 [illegible] the number 2 [illegible]

& the [illegible] the [illegible]

[illegible] the [illegible]

to the [illegible]

[illegible]

and the numerator indicating [illegible]

many [illegible] a [illegible] the [illegible]

[illegible] equal [illegible] which [illegible]

[illegible]

[illegible]

[illegible]

5.

Scales. smaller than nature, or one ten thousandth part of the actual dimensions of the land it represents; in other words, on this Scale a millimetre represents a decametre and the decametre contains ten thousand millimetres. Were a map or plan executed upon the same Scale or size as the object or area surveyed, or in fact nature itself, the Scale would be represented by $\frac{1}{1}$. In a country where, as in the United States, one is used to the employment of the foot, yard &c. as measures of distances, there is obtained, perhaps, a better idea of the Scale of a map when it is known that a mile is represented by a certain number of inches, and

B.

Scales.

as we are not generally acquainted with the French linear measures, or accustomed to reckon our distances by them, the system founded upon them is regarded by many as at best awkward in application, and as not affording an immediate and clear impression of the relation of the Scale of the chart to that of the area it represents.

Among a people where a decimal system is in common use the "natural" Scales are the most convenient; but they are hardly so when this is not the case. If we were familiarly acquainted with the length of the Kilometre, it would be very simple and natural to express the Scale by

Scales. the centimetre, or any small number of millimetres; but as we are not, the relation of the inch to the mile, with which we are familiar, is the most easy and employed with most facility.

From the gradual movement, however, throughout the civilized world towards the adoption of the decimal system of weights and measures, and particularly its recent legalization in our own country, and from the unquestioned fact that the French system is the simplest and best in all respects hitherto devised, it is probable that the employment of this system of Scales by the Coast Survey is merely anticipatory, and no one, after having be-

8.

Scales. come versed in, and accustomed to it, is ever inclined to go back to the old methods.

The Commission adopted the following Scales.

$\frac{1}{2.000}$, cities, towns, villages, also battle-fields, canals and field works.

$\frac{1}{10.000}$, ordinary topographical field charts.

$\frac{1}{20.000}$, reconnaissance in time of war, plans of battle.-

$\frac{1}{50.000}$, & beyond, engraving. But at the present time the Government Survey of France is carried on, on a Scale of $\frac{1}{20.000}$, and the maps engraved on $\frac{1}{80.000}$, while the Corps des Ponts et Chaussées (bridges and roads) employ $\frac{1}{5.000}$ in the field.

9.

Scales [illegible]

[illegible] the [illegible] [illegible] [illegible]

[illegible] than [illegible] [illegible]

the scale generally used for [illegible]

work, while in other [illegible]

but little [illegible] much [illegible]

[illegible]. But when the [illegible]

[illegible] for fine work [illegible]

[illegible]

[illegible] $\frac{1}{2000}$ [illegible]

in [illegible] [illegible]

[illegible]

[illegible]

would [illegible] needed [illegible]

[illegible]

[illegible] necessary [illegible]

[illegible]

10.

Scales.

for engraving when charts are published ranging from $\frac{1}{10.000}$, small harbor chart, to $\frac{1}{400.000}$, general coast chart, upon which the usual Scales of miles are engraved.

II Scale of Equal Parts.

Although, in a dissertation upon the Plane Table, it may be taken for granted that the use of the Scale, and of other of the simpler instruments is already understood, yet, for the benefit of the very young and unpracticed student, at the risk of being regarded as

47

Scales.

[illegible] [illegible] [illegible] [illegible]
[illegible] the following [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible].

What the [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] necessary to [illegible]
[illegible] [illegible] for the purpose [illegible]
[illegible] the [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] for this purpose [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] of [illegible]
[illegible] [illegible] [illegible] [illegible]

12

Scales.

No. 573 [illegible]

[illegible]

[illegible]

[illegible]

It is [illegible] that when the [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

and one is always

[illegible]

[illegible]

[illegible]

13.

Scabies.

[illegible]

Hospitals [illegible]

with [illegible]

[illegible] the other [illegible]

[illegible] embracing [illegible]

[illegible] therefore

[illegible]

[illegible]

[illegible] cases. The [illegible]

[illegible]

Great Chest [illegible]

[illegible]

[illegible] of the [illegible]

Hospitals throughout the

[illegible] as follows:-

[illegible]

[illegible]

9.

Three Point Problem.

1.

3 Pt Probm

A full discussion of the theory of the determination of points by graphic triangulation upon a projected sheet by means of a Plane Table, may be given at some future time, but at present, for all practical purposes, a statement of the Problem upon which this operation is founded, and according to the rules of which it is executed, followed, in the succeeding article, by a verbal solution of those cases where errors are liable to occur in field work, is all that is necessary.

The method by which, when the positions of three points

2.

3 Pt. Probm of nature are given upon the projection the position of a fourth point is obtained with the Plane Table set up at that fourth point, is known as the Three Point Problem.

Given 3 points in nature A, B, C, (Diagram No. 2) and the corresponding positions of the three ~~points~~ points on the Table represented by a, b, c, to find the position upon the Table of d corresponding to the fourth point D, in nature, by setting the Table up at the latter point. If we determine the angle ADC = m and CD B = n, then by means of these

3.

3 Pt. Probm. angles (that is the angles which are formed by the lines of vision from D to A, C and B, the point D is fully determined, because it is the only point at which lines drawn to the points A C B will form the same angles = m and n. To understand this imagine a circle so drawn, A and C, that the angle at the circumference measured by the chord A C = m, and through B and C a circle with the angle at the circumference = n then these two circles will intersect in one more point, D, besides the point C, and only at that one point D will A D C = m and C D B = n;

4.

3 Pt. Probm.

and there is not another point at which A B C will form angles = m and n. Then since in similar figures homologous angles are equal, d must form with a c b the same angles m n. The whole Problem, therefore, is to determine the angles m and n and the position of the point d, so that the angles a d c = m and c d b = n. It also follows in an analogous manner that there is only one point, d, which will fulfil these conditions.

The solution by the angles m and n is not applicable, when the point D is upon the

3.

3^{d} Prob^{m} circumference of a circle passing through A B C. or in a straight line with A B C. In the former case the angles *m* and *n* will not only belong to the point D; but every point of the arc, A D B will make the same angles with A C B, for the two circles constructed upon the chords A C and C B as before, will be one and the same circle

When D and A B C lie in the same straight line then the angles *m* and *n* are equal either to 0°, or 180°, which is the case with any other point in the line besides D.

10

Field Work.

1

Field Work

I. Organization of Party.

In organizing a party for field work it is necessary to have two men to carry the table. This duty is a responsible one, [illegible] with the instruments, & [illegible] under no circumstances [illegible] the topographer [illegible] it work [illegible] those to select the chief [illegible] of the party. In some sections the [illegible] of carrying the table is quite [illegible] which [illegible] man should be [illegible] [illegible] with the [illegible]. The [illegible] keep the pencils sharpened, [illegible] when a [illegible] [illegible] he [illegible] [illegible] [illegible] the [illegible] [illegible]

2

Field Work.

[illegible] [illegible] [illegible] [illegible]
the instrument. He should always have
with him a spare piece of [illegible]
[illegible] [illegible] quite sensible. Two [illegible]
are needed and two or three others
with signals attached. Elevation and
other working characters & special
offices as they may be required. The
minimum number necessary for [illegible]
work with a Plane Table is [illegible]
is two [illegible] and [illegible] [illegible]
by. Satisfactory work has been [illegible]
[illegible] with these [illegible] [illegible] [illegible]
[illegible] with [illegible] [illegible] [illegible]
[illegible] with less facility.

3.

eld Work

[illegible] than five and one half [illegible] [illegible] table of [illegible] the [illegible] [illegible] the number of a [illegible] determined by [illegible] operator. —

The altitude of each [illegible] station is stated by the Chief of [illegible] [illegible] on the [illegible] of the [illegible] [illegible] at the [illegible] and [illegible] to be [illegible] by the [illegible] of the standard [illegible] of the telescope [illegible] operator [illegible] [illegible] in the [illegible] by one of the [illegible] furnished to the [illegible] when the [illegible] is set up at a station [illegible] by the [illegible] [illegible] but not of [illegible]

4
Work.

by [illegible]

[illegible] pieces of [illegible] by [illegible]

and a table for reference [illegible]

be being used for a table frame [illegible]

but cheapness in taking out [illegible]

drawing it in the bag so [illegible]

[illegible] the bag to paste [illegible]

[illegible] adjustments [illegible]

fold of the bag [illegible]

the ground and not [illegible]

[illegible] to the weight so as to [illegible]

little inconvenience. The metre scale is

best fastened under the clamps which

hold the paper to the table where it

is close at hand ready for reference.

It has been suggested that it would

be [illegible]

ield Work

advantage to have it engraved upon the side of the [illegible]. The pencils, eraser and India rubber can be carried in an outside breast pocket the points of the dividers when not in use being protected by inserting them into the end of the rubber. A very neat compact arrangement for carrying the scale pencils etc is a small leather case [illegible] x 2½ inches with strap and buckle. It should be made large enough to accommodate upon the opposite sides of the scale when it is in three or four pencils and the dividers protecting the points of both; the whole carried in a leather pouch 11 x 4½ inches.

6

ield Work. [illegible]

[illegible]

[illegible]

[illegible]

[illegible] When the table is set up [illegible]

[illegible]

[illegible] upon the [illegible]

the [illegible]

[illegible] sheet [illegible] the [illegible]

upon the table [illegible] the [illegible]

[illegible] table [illegible] the paper [illegible]

[illegible]

is not always [illegible] the most convenient

[illegible] the [illegible]

[illegible]

7.

ld Wort.

[illegible]

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Field Work.

[illegible]

[illegible]

The table must [illegible]

[illegible]

9.

ield Work.

[illegible] may [illegible] [illegible] [illegible] [illegible] [illegible] levels.

[illegible]

the assistance in the field [illegible] [illegible] which may be attached to a topographical party, should be observed.

1. Strict attention to [illegible] [illegible] and exact [illegible], and [illegible] compliance with the instructions given by the Chief of party.

2. No conversation between with the men except in relation to their duties and then only in the name of the Chief, or by delegated authority; avoid unnecessary harshness [illegible] [illegible] them to respect you.

ild Work.

11.

ld Work.

on[illegible] object, and then [illegible]

be parallel [illegible] parallel [illegible]

"[illegible]."

8. In carrying the [illegible] take [illegible] to [illegible] proper station and [illegible] bring [illegible] keep it horizontal and let [illegible] thoughts be [illegible] object in view.

9. Place the [illegible] and when once placed do not change it, though you may subsequently discover what you may consider a more advantageous position.

10. [illegible]

[illegible]

12

Field Work

[illegible]

[illegible]

11. [illegible] ready [illegible]

12. [illegible]. Do it [illegible] of [illegible]

13. [illegible] work the [illegible] best and seek [illegible] from the Chief of party.

14. Take advantage of [illegible] to perfect yourself in drawing, making projections, [illegible] sketching, and all [illegible] [illegible] to have [illegible] of a [illegible].

15. [illegible]

13.

Field Work.

be [illegible]; [illegible] [illegible] [illegible] the [illegible]

face by practice with the [illegible]

[illegible] [illegible] the [illegible] heights of [illegible]

that you may be able to judge of com-

parative elevations and estimate the

approximately at a glance. [illegible]

[illegible] and give greater [illegible]

and secure uniformity.

16. Cheerful compliance with [illegible]

[illegible] may not be strictly [illegible]

[illegible] pave the way to those [illegible]

[illegible] and friendly relations [illegible]

should always exist in every [illegible]

[illegible] party between the [illegible]

his subordinates. Never stand [illegible]

[illegible] on trifles, but [illegible]

[illegible] [illegible] [illegible] matters.

14.

II. Preliminary Work.

Field Work:

We are now to explain what [illegible] "Geographical" [illegible] for [illegible] the [illegible] and the [illegible] the instruments adjusted and [illegible] the [illegible] the [illegible].

As an [illegible] the [illegible] of the [illegible] must [illegible] of the [illegible] on the [illegible] in the [illegible] of [illegible].

Field Work.

[illegible]

[illegible]

16.

Field Work

The purpose of the work [illegible] [illegible]
upon the character of [illegible] [illegible]
the skill and judgment of the [illegible]

[illegible] [illegible] [illegible]
[illegible] objects it is usually necessary [illegible]
beforehand over the country to be [illegible]
[illegible] scale as well as [illegible] [illegible]
for subsequent determination and [illegible]
In the location of signals [illegible]
prominent points or [illegible] for [illegible]
forward lines, a great deal [illegible]
upon the good judgment of the [illegible]
placing them. Two methods are
followed: first the [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]

17

Work

Whenever there [illegible] [illegible] [illegible] [illegible] in view of the [illegible] [illegible] [illegible] [illegible] such as some features [illegible] [illegible] features for filling in the topography [illegible] available, & should be [illegible] [illegible] that in the course of the [illegible] [illegible] under such as favorable opportunities must be allowed to pass for [illegible] topography & determining [illegible] [illegible] [illegible] many at some future time [illegible] [illegible]. Advantage should be taken of [illegible] chances in the [illegible] [illegible] roads & ravines. There is [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] own stations with [illegible] [illegible] [illegible] [illegible] [illegible]

18.

Field Work.

[illegible]

ield Work

with permanent & peculiar marks as [illegible]
to prevent [illegible] [illegible] [illegible] [illegible]
have settled or settled [illegible]
[illegible] [illegible] [illegible] & each
etc. They should also be noted
with [illegible] in the [illegible]
having permanent objects so that
when they are disturbed, their location
may be found.

It is taken for granted that
those familiar with the manipulation of the
Table [illegible] directly connected with the
use & knowledge of trigonometrical [illegible]
for trigonometrical calculation [illegible]
[illegible] of the [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]

20.

ield Work

[illegible] [illegible] remarks that [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
Better [illegible] [illegible] [illegible] the [illegible]
[illegible] in the [illegible] [illegible] [illegible] [illegible]
[illegible] with [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] that all lines should be
drawn lightly and carefully. Use
[illegible] of the rule with a fairly hard
lead "6 H" Faber pencil and that we shall
use somewhat softer No 4 or No 5 Faber, the
former to be the best. If the table [illegible]
[illegible] be in proper condition the contact
of the fiducial edge with the paper will be
perfect throughout its whole length and
in drawing a line along the edge [illegible]
[illegible] be taken to [illegible] the [illegible]
[illegible]
[illegible]

Field Work

If the sole be at all raised from the paper at any point still greater care is to be observed lest the point of the pencil should run under the edge and thus deviate from a straight line.

It would be well for the [illegible] one to learn to observe with the left eye as well as the right, for obvious reasons.

The instruments should be kept scrupulously clean and free from sand or grit. The occasional [illegible] sheet of the Table and cleaning with soap and water [illegible] may be [illegible] necessary; and after being [illegible] put together it should be

22

[illegible] [illegible] [illegible]

[illegible] [illegible] the [illegible]

an [illegible] to the [illegible]

[illegible] [illegible] [illegible]

should [illegible] the [illegible]

of our foreign [illegible]

[illegible] [illegible]

[illegible]

The [illegible] [illegible]

which are not [illegible]

[illegible] [illegible] [illegible]

the [illegible] the [illegible]

III. [illegible] and [illegible] [illegible]

[illegible]

23.

Field Work

can be determined by three methods, by [illegible] intersection and measured distances. In the first of these the point must be seen from two or more occupied points [illegible] with regard to the point to be determined, in the second it must be occupied and in the third there must be a direct measured line and established direction from the points. As in the latter case [illegible] it is essential to see the station from two or more fixed points [illegible] from the station and [illegible] determined either by [illegible] [illegible]

Field Work

is more accurately, where the angles of intersection are too acute to be satisfactory.

These two methods of determination [illegible] applied to, and the horizontal angles which accompany them will now be shown.

Let A B C D R represent the board of the Plane Table upon which is placed the topographical sheet, the point of triangulation a upon the sheet representing the [illegible] the ground [illegible] the [illegible] [illegible] of the [illegible] [illegible] [illegible]

ld Work.

on the chart constructed [illegible] [illegible] [illegible] of the [illegible] [illegible] upon the ground [illegible] [illegible] by constructing large [illegible]. The [illegible] is next placed [illegible] on the occupied station [illegible]. [illegible] its position [illegible] so that the [illegible] [illegible] on the [illegible] are in range with the station of [illegible] signals or objects they represent [illegible] field. Then placed the point [illegible] the station [illegible] the [illegible] of the [illegible] in the ground [illegible] [illegible] upon the [illegible] [illegible] [illegible]

nd Work.

[illegible]
the top of the Stand [illegible]
[illegible]
to [illegible] of the [illegible]
[illegible] to the [illegible]. Place the [illegible]
at right angles to the fold [illegible]
when the beam [illegible] the [illegible]
[illegible] the [illegible]
table at last. [illegible] the [illegible]
[illegible]
edge of the table [illegible] the [illegible]
[illegible] point [illegible] the [illegible]
point [illegible] the sheet.

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Field Work

so that it shall bisect the two needle holes or plotted points on the paper as nearly as may be. The object end of the telescope being directed towards the signal or point B as shown by the [illegible] arrow head in the figure [illegible] the Table horizontally about its center with the hands until the object B is seen in the field of the telescope. Clamp the tangent screw and turn it till the vertical hair of the telescope [illegible] with the middle horizontal cross hair bisects the top or center of the object. The Table is now in position if the plotted points be correct and the other objects sighted [illegible]

ield Work. Orient the table [illegible] [illegible] [illegible]
[illegible] when the point [illegible] [illegible]
and the point occupied are in the same
vertical plane with the line of sight
the edge of the rule being upon the two
plotted points, the one perpendicularly
over the occupied station and the other
to the station observed upon. [illegible]
of the correctness of this [illegible] [illegible]
upon the point a again [illegible] [illegible]
points a and b consecutively, [illegible]
the two signals B and C are [illegible]
the vertical cross-hair of the telescope
in the same manner as A the [illegible]
is assured and the meridian of the
sheet is parallel to that of

Field Work. the earth the lines joining all the points and their respective projections showing in their true relative positions.

It will sometimes happen that the upper plate once attached to the Table after it had been clamped and the tangent screw used to put the Table in position has a tendency to change still further with a sudden movement or slight jerk and this movement may not occur until called by the observer working about the Table and walk unobserved by the observer. This may arise from the two discs being screwed too closely together and the force [illegible]

Field Work

[illegible]

ield Work.

adjacent station to that number [illegible] level [illegible]. The use of the [illegible] check where the level is [illegible] about that point as a centre, until the forward end of it [illegible] to the vertical axis and then a line [illegible] drawn along the axis of the [illegible] is sufficiently far to reach the [illegible] distance to the chest [illegible] point [illegible] and it can be out of the [illegible] next check line is to be drawn in the same manner. But nothing [illegible] checked, unless it is desired to [illegible] lines to other points which may be subsequently occupied, lines to be afterwards connected should be run to each station as [illegible]

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ld Work

upon the work is obtained. A [illegible] [illegible] the [illegible] of [illegible] [illegible] marked as on the [illegible] [illegible] [illegible] [illegible] [illegible] etc. [illegible] and lines of reference to objects [illegible] particular areas at [illegible] to the [illegible] is obtained by the [illegible] [illegible] [illegible] etc. should be [illegible] by the [illegible] [illegible] [illegible] is not [illegible] [illegible] should be observed [illegible] [illegible] in the contours at the [illegible] and to serve as a point of reference in taking sights at other places the method of doing which will be [illegible] [illegible]. The necessary [illegible]

33.

ld Work.

[illegible]

[illegible]

[illegible]

the [illegible] and the [illegible]

[illegible] for the [illegible]

it be necessary to [illegible]

the [illegible] of the [illegible]

When [illegible] from [illegible]

[illegible] it is the [illegible]

[illegible]

[illegible] with the [illegible]

Take care [illegible]

[illegible]

will [illegible] and be [illegible]

[illegible]

ld Work.

which is fixed by the three points on the plan of the table only.

Thus far has been given the method of resecting a station by determining point by orienting the table and taking forward intersections over traced lines. For better illustration we will have recourse to another figure.

Now let the letters in Diagram No. [illegible] be the same as in Diagram No. [illegible]. The table is oriented in the present station.

Work. I, [illegible] in the [illegible]
projection to mark the table [illegible]
over the point I, in the position [illegible]
appropriate position parallel to [illegible]
at the other stations. The rule is
then placed along the former [illegible]
(now called the back line) as per [illegible]
passing through the point p, and [illegible]
the sights on p, are set [illegible]
along the edge and the telescope [illegible]
[illegible] the signal S as shown [illegible]
arrow and the table oriented. The [illegible]
is now moved horizontally until [illegible]
center [illegible] [illegible]
of tangent [illegible] with the [illegible]

Field Work

to the signal & read the vertical circle of the telescope & repeat once or so inverted. The position of the point representing upon the sheet the projection of the station D, in relation to the other points is now to be ascertained. It is known that it must be somewhere upon the line ℓ drawn from the point ℓ towards the signal D and its exact location on that line is to be found by what has been termed "section." The side is then placed with its edge touching one of the plotted points first as b which will give a closely cut angle the nearer 90° the better with the line f or l and is

[illegible]

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Field Work. [illegible]

[illegible] the [illegible]

[illegible]. The [illegible]

[illegible] circle the line of [illegible]

the point of rotation is the point of

[illegible] to the [illegible] of [illegible]

[illegible]

[illegible] two distant points [illegible]

[illegible]

[illegible]

intersection of two lines drawn [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Field Work. [illegible] reflection [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] the distance is [illegible]

[illegible]

[illegible] with the [illegible]

[illegible]

difficult to [illegible]

[illegible]

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Field Work.

[illegible] of the same [illegible] with the [illegible] should be [illegible] to the same [illegible]. The point where the intersections [illegible] drawn from [illegible] the drawing [illegible] which [illegible] each [illegible] accurately [illegible] the [illegible] through the [illegible] direction from left to right and the [illegible] thus definitely fixed upon the map, produce through each marked such [illegible] Thus the determined can now be used in [illegible] for the determination of other stations. New lines to such other objects as it may be [illegible] necessary should be taken [illegible] straight lines and then followed [illegible] sketching to fill in the details of the sheet.

40.

Field Work: [illegible] from station between stations instead of taking intersecting lines to each required point. In conclusion of this subject we will employ a third figure (Diagram No. 5)

The Table is now assumed to be upon the ground which it was thought unnecessary to mark on the diagram, through which the required line [illegible] is supposed to pass near its edge over the station and the point a [illegible] [illegible] the projection of the [illegible] upon the map is determined by sections as already described or by the use of the line

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Field Work

& and the points 2 and 3 [illegible]
through the latter are not absolu-
tely necessary. The points on the [illegible]
& such intersections have been [illegible]
to determine [illegible] the church, & other [illegible]
points [illegible] perimeter. The [illegible]
and tree may also be used for this pur-
pose. Other & second interesting [illegible]
are taken from 2 & from the other [illegible]
windmill spire etc. with their [illegible]
definitely fixed upon the map [illegible]
[illegible] and marked and their [illegible]
well determined. [illegible] can be [illegible]
points for the determination of other
stations. This is the final [illegible]
[illegible]
[illegible]. [illegible]
[illegible]

Field Work

be run with the reference to some established point from the point compelled to observe the impossibility of the Table or to correct any defects of the true position which may have taken place.

If upon going to a former traced or object to which a line has been taken it is found that it cannot be reached or that it is in such position that a sufficient number of points must be passed from it for any reason it does not answer the desired purpose, a point in range between the two stations or where the prolongation of the line [illegible]

113.

Inlaid Work. from time to complete. Setting [illegible]
wire between two plates and by means
of two wooden plungers passing [illegible]
with short white [illegible] [illegible]
are made on the line and [illegible]
of which [illegible] the [illegible] [illegible] [illegible]
the [illegible] [illegible]. Each plan [illegible]
alternately to the right and left [illegible]
as may be required [illegible] [illegible]
until each square [illegible] [illegible]
[illegible] [illegible] back to [illegible]
seen in the [illegible] [illegible]. The
table can then be [illegible] [illegible]
anywhere on the line. It [illegible]
be a [illegible] [illegible] the [illegible].

ield Work.

signal may also be found by a [illegible] alignment with the [illegible].

When by accident in draw-ing a forward line from an [illegible] point, near which stood the pre-dotted marker, a second place where the rule is not set on the proper [illegible]-pile, and the error is not [illegible] till the forward signal is reached, instead of going back to [illegible] the rule and draw it from the [illegible] it can be [illegible] by drawing from the correct station [illegible] the false line by means of the theodolite, the largest [illegible] [illegible] [illegible]

45.

ield Work.

[illegible] the [illegible] [illegible] [illegible]
actual distance from the [illegible]
point to each station [illegible] the
line. Of working [illegible] [illegible]
and formed the line.

IV. Of Points and Lines.

The accuracy of the work in
a Topographical sheet is directly
and mainly dependent upon the
correct determination of points
and a want of care upon [illegible]
of the capabilities [illegible]
those [illegible]

46

ical Work.

[illegible]

Finding [illegible] position [illegible] as well as the position of [illegible] is one of the [illegible] and [illegible]. When [illegible] with [illegible] and [illegible] work exceeds the [illegible] upon which it is [illegible] become [illegible] subsequently [illegible].

When [illegible] we have [illegible] point [illegible] lines drawn from a number of [illegible] with the table [illegible]

The position is retained but when they do not thus intersect the source of the difficulty may be found either in error of triangulation or construction 2nd in a faulty projection & plotting of the points or 3rd in the irregular expansion or contraction of the paper — the first two when at all great can only be corrected by a revision of the work of triangulation and projection while the latter if not sufficiently large to warrant an entire rejection of the sheet can be remedied only by the judicious action of the topographer with the Plane Table in the field.

48.

ield Work

When points disagree within very moderate limits the resultant error can be distributed by distributing the error among the points in the proportion of their distances from the occupied point so as to reduce the effect of the error of these substitutions and on the position of the occupied point, but he may be safe in considering such lines determined from his point as corrected as more accurate and [illegible] than the plotted points themselves, and use them as such. A [illegible] error of 20 meters on a scale of [illegible] can generally be reduced at the point of [illegible]

49.

ield Work. position is an almost, if not quite, imperceptible quantity.

The topographer should be very chary in rejecting points as unfit for use. No matter what the apparent disagreement may be, one should not hastily throw aside one set of points and accept another because one set appears to agree and the other to disagree. But the positive acceptation of a series of points of whose accuracy you have become sure, and of another series of whose inaccuracy you are equally certain, entitles the preference of

Field Work.

one at one another at once is not only permissable but obligatory. It should always be remembered that exhaustive and careful investigation in the field and close examination of the projection, plotting and data of triangulation are to be made before any point or set of points is condemned.

Having now considered the problem of the correction of errors originating in the inaccuracy of the main points or points of triangulation we will proceed to examine the question where these points

ield Work

Triangles [illegible] yet [illegible] [illegible] [illegible] from the present use of [illegible].

In determining the position of a point by means of the well known Three Point Problem, when the Table is not properly oriented, the lines drawn from the three known points will not intersect in one point except when the four are on the circumference of a circle, a most [illegible] circumstance in Plane Table work. In this case the problem for position of the station is indeterminate, the angle at the station being inscribed.

Field Notes angle is measured by [illegible] intercepted on the circumference [illegible] line of sight to the signals and [illegible] arc remains the same at whatever point of the circumference the station is situated, and therefore being [illegible] it does not fix its position. When the table is out of position exactly 180° the intersections will also be in a point. But this is regarded as an impossible occurrence in plane-table practice.

Except in these cases then, when the table is not correctly oriented but nearly so the lines will form a small triangle, or two of them will be nearly parallel intersected by the third. The true position of the point where all the three lines will intersect is to be found from these false intersections. [illegible]

[illegible]

Field Work.

situated in regard to these lines in the act proportion as the distances to the points observed, and approaching in proportion to the acuteness of the angles which the lines form with each other that is it is most distant from the line drawn from the most remote point and nearest to that drawn from the nearest point.

The following rules will serve as guides in finding the true position of the point and usually one or two trials will give it exactly. It can be found geometrically by the intersections of arcs of circles drawn through each two points and the point of

Field Work.

[illegible] [illegible] [illegible] [illegible]
then the triangle of error may
impracticable in the field except [illegible]
points are so close to each other [illegible]
one can readily perceive where the point
should be drawn which then [illegible]
in fact a matter of judgment and
correctness of eye and as such practice
will in time enable the topographer [illegible]
locate the point upon the chart [illegible]
the alidade without the aid of a geo-
metrical construction It is hardly
worth while to give the problem here.
The solution by Bessel is perhaps
the most perfect and that [illegible]
the true point

ield Work.

be found by means of the triangle of error as described in the [illegible] Survey at [illegible] and used; they [illegible] are open to the same objection as the foregoing of indeterminability [illegible] where rapidity of work is desired and where experience will give facility in finding approximately the true point more rapidly than the application of any formula. Practice and judgment in [illegible] have thus far been found to supersede the above methods of geometrical [illegible] solution. In fact the moment the plane table is in position the traveller will know the angle of error, and the question to be answered is in what direction and by what [illegible]

[illegible]

[illegible]

ld Work. The drawings of [illegible] the [illegible] Movement of the table to the right [illegible] direction of the movement of the hands of a watch; to the left, the reverse.

Rules

for finding the True Point.

1. When the instrument or point occupied is within the great triangle formed by lines connecting the three objects observed, the true point is within the small triangle of intersections on the sheet. When the point occupied is without the triangle the true point is also without the triangle of intersections and is situated to the right or left of the small triangle according as the table is out of position to the left or right.

The [illegible]

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Remark. particularly in Diagram No. 8 [illegible]
A B C represent the points observed and
ab ac bc the lines forming the [illegible]
intersections drawn from them.

2. When the point occupied is without
the triangle formed by the three objects
and within the circle passing through
them, the true point is without the trian-
gle of intersections, and the line drawn
to the middle station lies between the
true point and the intersection of
the other two lines. See Diagram No. [illegible]
This also includes the case when [illegible]
circle

al Work.

occur in practice when the three given ed points are in a straight line, the straight line being the arc of a circle whose radius is infinite.

Rule. If the line from the middle point is to the right of the intersection of the two lines turn the table to the right.

See Diagram No. 8 in which A B is the line drawn from the middle station.

3. When the point occupied is both without the triangle and the circumference, i.e. the true point is without the triangle of intersections and upon the same side of the line drawn from the middle point to station as the intersection of the other two lines.

Rule. If the line from the middle point is to the right of the intersection of the other two [illegible] turn the table to the left. See example Diagram

ield Work

[illegible] 9) [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
case, but is an [illegible] which [illegible]
be regarded as indeterminable in [illegible] to
Field Work when the point occupies [illegible]
the circumscribing circumference.
4. An exception to case 3 occurs when
the point occupied is without the [illegible]
formed by the three points and [illegible]
without the circle, and is [illegible]
the nearest signal of the middle [illegible].
In this case the true point [illegible]
the triangle of intersections and the
line drawn from the middle [illegible]
lies

awing

between the true point and the intersection of the other two lines (diagram for Rule). If the line from the middle point is to the right of the intersection of the other two, turn the table to the right.

5. When the point required is on the side of the triangle, or situated nearly upon a line connecting one of the observed stations the lines drawn from the plotted points on the right side will not meet but will appear nearly parallel, and will be intersected by the line drawn from the middle point; the true point is then between the two lines, and to the right of the intersecting line, when the

Field Work

line from the [illegible] passes [illegible] moment [illegible] from the left [illegible] [illegible] with the [illegible] [illegible] and [illegible]

Rule. When the line from the right [illegible] station is approximate [illegible] [illegible] the one point [illegible] produced, the line drawn from the [illegible] [illegible] line will also [illegible] but the true point will be [illegible] the line drawn from the third station [illegible] to the right or left of the true point [illegible] as the table [illegible] to left of the two [illegible] [illegible] from the [illegible] point [illegible] to the true point.

[illegible] of the line from the [illegible] [illegible] of the station [illegible]

21st Nov. [illegible] for the [illegible] figure
[illegible] on the [illegible] of the
preceding. The two figures in the
first section and the third figure [illegible]
[illegible].

These cases may perhaps be stated more systematically as their [illegible] with their specifications under the problem.

1. When the point is within the triangle.

2. When the point is upon the side of the triangle.

3. When the point is without the triangle & when the point is within the circumscribed circle. This includes the case of the 3 [illegible] in a straight line.

4. When the point is without the circumscribed circle [illegible] adjacent to a side of the triangle.

5. When the point is without the circumscribed [illegible]

63.

ield Work.

As has already been remarked, experience and practice will enable the topographer to obtain his true point very rapidly.

It is not at all uncommon for an expert hand to station himself in a position without any lines whatever, and in two, or at the utmost three trials, obtain the correct point. This comes, however, only with patient practice, and until this facility is attained the foregoing rules and suggestions will serve as guides.—

In taking lines of inter-

and Mem. several lines to a point of departure from a series of stations, when these lines do not coincide in one point, as they will always [illegible] derived from [illegible] of unequal [illegible], the error should not be divided equally between them, but in proportion to their lengths.

It should be borne in mind that very short lines from a determined point – as for instance to the corners of a fence or wall when the Table occupies the centre of the intersection of two streets, may be taken with no apparent error when the Table is deflected to some extent from its

ld Work. from experiment. But that is the case, a prolonged line will be considerably out at its farther extremity.

Forward and back sight work for position is the [illegible] method for the Plane Table. If the Table is absolutely in position the forward lines derived from the back sights are the most correct lines upon the map. If there is an error in orientation such lines are in error in proportion to their lengths, the longer the line the greater the divergence. The second

Field Work.

of great liability to error in position: therefore, too much reliance is not always to be placed upon foresights [illegible] back lines for position. To take in sighting back on a very short line some large object, not suitable for accurate bisection, and without which an [illegible] tion is liable to occur.

A long line should [illegible] be obtained by the prolongation of a short one from a back station where there is no small check line, or some other point in that prolongation already fixed.

It will be apparent

6

Work

the nearer [illegible] the angle of intersecting lines [illegible] right angle the more clearly the point will be defined; and as intersecting lines are obscured in proportion to the smallness of the angle formed by them, acute intersections as far as possible should be avoided, and even when they are crossed by a third line at a satisfactory angle, a fourth line or an accurately chained distance from a well determined point is advisable. —

The necessity for dependence upon a measured line, not an established direction [illegible], for [illegible]

ld Work.

time is sometimes unavailable. The [illegible] for minor details [illegible] never be [illegible] when other [illegible] are available. Occasional checks are very important aids in a [illegible] piece of work in lengthening consecutive series of stadia. Lines for position should be [illegible] without [illegible] test of accuracy. It is safer to [illegible] [illegible] unless the supply of signals is ample and these are favorably located.

A judicious use of range lines from established points or signals will much economize time and facilitate work. Two range lines from well determined points are [illegible] to

60

a Work. four intersecting lines.

Tangent lines can only be used for determining the position of points in certain kinds of [illegible] which of these small parts [illegible] the outlines of other objects [illegible] unimportant locality; and are unsuitable for any purpose in which accuracy of delineation is expected, save when they form a polygon or the segment of a polygon [illegible] absolute convexity at all points is to be represented and even then the points or objects should be visited and sketched in.

7°

a Work. Dribble.

V. General Directions.

In a preceding article it has been stated that in the course of the routine established in the Coast Survey, as the Topography follows the Triangulation, so the Hydrographer is expected to proceed the Topography, and as it is the duty of the Topographer to locate and determine the shore line, so it is also necessary to state that they should be so placed as to furnish the hydro-

7

Field Work

the work of the survey [illegible] is desirable for the determination of stations on the water. It is usual to mark all stations occupied along or near the shore by a peg driven into the ground with stones about them and give their locations when the work furnishes the brief of all the topographic party, and he can then select such as are best adapted for his use. Natural or artificial objects seen along the shore or in prominent points from the water, such as lone trees, white rocks, prominent houses and posts on wharves etc. should be determined and marked.

ield Work

across the creek. The crossing points [illegible] stakes between the lakes of the [illegible] which the stations should be [illegible] secured above the mark of the [illegible].

Lines to buoys and other permanent floating objects should as far as practicable taken at the same stage of the tide or direction of current, or the dates of the [illegible] noted at the time of observation.

In the determination [illegible] tracing upon the chart of the [illegible] line, so much in its outline is [illegible] really dependent upon the [illegible] and force of the winds that no fixed rules for guidance can [illegible]

Field Work.

years. The delineation of the [illegible]
by means low water mark whether [illegible]
reach it; and where it is beyond
the reach of the Plane Table, and
there are no marked points for deter-
mination, or is of a character that will
not admit of setting up and mov-
ing the instrument, as along the
marshy shores of the points where the
middle shoals exist for the
most among the shifting sand-
banks of our great estuaries and
bays, it must be left to be traced
by the soundings and tidal observa-
tions of the hydrographic parties.

emark. It is always best to determine the height and duration of both at spring and neap tides. Having learned the range of tide the Topographer knows how long he can work without one.

When, on the occurrence of any great or unusual storm or freshet during the working season, the low water line which has already been surveyed is found to have changed in form or locality it should be resurveyed and both the old and new outline retained on the

75.

ld work. sheet with the appropriate notes.—

As a feature which is quite interesting and important under certain circumstances to the hydrographer, low water springs, having their origin and outlet below the high water line should be shown on the chart where it can be done, in the regular routine of work. ~~and~~ All grassy shoals should be delineated.— They are always found in water scarcely agitated by waves or currents, and their shape and outline on the channel side is a very marked feature, and a good measure of the power of the

70.

d Work

current. Each [illegible] should be put where the [illegible] [illegible] sufficient accumulation of the sand or soil and a current [illegible] under the [illegible]. Then gradually [illegible] with "[illegible]" a bottom about three feet of depth in water.

Orientation by the declination or compass needle alone is an unreliable process to obtain [illegible] tions to rough sketches of reconnoissance; but it [illegible] be used as [illegible] [illegible].

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12 March

[illegible] of the instrument which is [illegible] stations in default of sufficient points being to obtain an approximate position. It is used by placing the straight edge of the box parallel to the needle when in magnetic meridian, previously marked upon the sheet and revolving the table until the needle points to 0° on the [illegible] on the graduated arc on the end of the box. The magnetic meridian is roughly obtained at any well determined station when the latter is properly oriented, by the use of declinatoire itself the meridian line being drawn upon.

/b

n Work. The sheet may be [illegible] [illegible] to any scale. The smaller [illegible] convenient.

In sketching or drawing the country care should be taken to show the size of natural objects, the scale being followed as far as possible, but in some cases, where [illegible] [illegible] apparent, it may be requisite to exaggerate somewhat, but very cautiously. The topographer should learn to measure from nature readily and at once without being obliged to resort to instruments. By working

ield Work.

slowly and carefully at first this will be attained in due time.

Too frequent use of the india-rubber disturbs the fibres of the paper and renders the subsequent inking less neat and clear. The drawing should be plain and distinct, so as not to be obliterated easily by the movement of the alhidade over the paper; but not so dark or heavy as to blurr. The object should be solely to represent accurately the surface and elevation of the country surveyed, and it should be easy and natural, and not merely a stiff copy of conventional signs. Nothing should

80.

al Work.

be [illegible] instruments and [illegible] topographer [illegible] Astronomical, [illegible] and [illegible] As far as practicable the work should be drawn in the field, under the eye. Sketching and plotting in the office from notes is objectionable unless the country be seen [illegible] for examination in case of doubt, or a defective sketch, or of error of orienting.

It is well to repeat that too great care cannot be taken in the manipulation of the Plane Table. There should be no pressure, even in moving the alidade both [illegible] and the arm should [illegible]

ld Work.

[illegible] [illegible] of the [illegible] at the [illegible] to [illegible] over the surface of an [illegible].

The topographer should [illegible] to distinguish as a matter of [illegible] in point of time between the [illegible] importance of different topographical features. While it should be the object to do all the work accurately [illegible] should be [illegible] [illegible] operations of such accuracy [illegible] correct representation of the [illegible] settled streets of a town [illegible] [illegible] of an unimportant [illegible] [illegible] [illegible] out of the [illegible] [illegible]. Experience shows [illegible] [illegible]

ent Work [illegible]

11.

Contours.

1

ntours.

Contours.

Of these the one feature which most peculiarly distinguishes one section of country from another, imparting to it the most striking characteristic, and to which all the accidents of ground are subordinate, is to be found in the irregularities or changes of level of the surface; and it is the correct representation of this feature that calls forth the best skill and judgment of the topographer, and upon which the value of a map most materially depends.

So important a problem is [illegible] in this section of topography that [illegible] [illegible]

2

ontours.

1st [illegible] of [illegible]

[illegible] of the [illegible]

[illegible]

2nd The [illegible]

[illegible] of the [illegible] of the [illegible]

[illegible]

[illegible] "++++ [illegible]

[illegible]

difficile [illegible]

établir [illegible]

entre [illegible] et le [illegible]

++++".

Previous to the commencement of such, it is well to become [illegible] some knowledge of the [illegible]

[illegible]

[illegible]

3

ntours- [illegible]

district with materials [illegible]

whether smooth and other [illegible]

such character probably [illegible]

worker will suggest to the [illegible]

the best method of operation and [illegible]

him to pursue a general plan of [illegible]

which will result in economy in point of

time and as a consequence [illegible]

the continuity of Contours from [illegible]

as the work progresses.

By keeping

in view the characteristic features of

11.

[illegible] 1873 the line in the [illegible] [illegible] [illegible] nearly the topography with the [illegible] just as pronounced to a third [illegible] is once formed though [illegible] [illegible] by [illegible] which he could not [illegible]. It is to be observed that the [illegible] [illegible] developed in these forms [illegible] [illegible] appear to follow [illegible] [illegible] [illegible] a general system of nature [illegible] widely detached localities [illegible] [illegible] areas may appear to be exceptions from the general law. When these exceptions are found they can usually be proved to have a general breach of the [illegible] with this law and will be found to conform widely to the [illegible].

[illegible] [illegible] [illegible] [illegible]

[illegible] –

5

ontours

Thus the principal ridges will be found to lead in one general direction, either running parallel with the main range which lies farther in the interior, or forming spurs at right angles to it. Along the coast the latter is generally the case as we there usually find the termination or the extremity of some main promontory or inland range. Where a single isolated hill is found or a line of them parallel as is sometimes the case so [illegible] regular [illegible] as to be compared to half a watermelon [illegible] appearing [illegible] without any appearance of the [illegible] [illegible] [illegible] [illegible]

6

Contours. [illegible] [illegible] [illegible] [illegible] [illegible]
general [illegible] the appearance of
rifted mass of broken bluffs with
face and cliff surfaces [illegible]
without any apparent regard to [illegible]
regularity, it will be found that [illegible]
and delineation when followed [illegible]
will show that the contours [illegible]
to their local complexity and [illegible]
of outline, follow the same general
direction as the main ridges [illegible]
sheet, the water courses frequently [illegible]
the depressions and valleys [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible]

ntours [illegible], or lines [illegible]
[illegible] of their relative [illegible]
[illegible] and tide, [illegible]
[illegible] is formed which [illegible]
[illegible] delineation, and the [illegible]
[illegible] striking character and [illegible].
[illegible] should be portrayed with
all possible [illegible] in [illegible]
[illegible] useful aid in the study of
[illegible] relative branch of geology.

To the [illegible] and
[illegible] physical geographer the [illegible]
[illegible] mapping of [illegible] is [illegible] for
[illegible] familiar the [illegible]
[illegible] eye view can discover the [illegible]
[illegible] features which are [illegible]
[illegible] of an extended district.
[illegible] district is [illegible]
[illegible]

8.

ntours traveling dunes will be found.- these are distinguished from other hills by the contrast between the *fore slope* (on the lee side) which is steep, and the rear slope (on the windward side) which is gradual. Successive surveys on sandy coasts, where close attention has been given to the Contours of the dunes, are of great value ~~in~~ for comparison, if every detail is carefully given. Even in places where the winds are uncertain, proper Contouring discovers dunes which travel along the resultant of the forces, - and in the direction of this resultant the great dip of the foreslope is found. For such dunes, the several slopes for different points of the compass are equally interesting.

On exposed points

y.

ntours. projections [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] they [illegible] [illegible] ridges of sand [illegible] [illegible] other ways. It has been [illegible] [illegible] time [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] Contoured topographical [illegible] of the localities where they are found would add [illegible] [illegible] a study of [illegible] teresting subject. Contours [illegible] [illegible] [illegible] their [illegible] [illegible] exhibit the [illegible] of them, which would not be done by [illegible] representation by hachures.

The delineation of [illegible] along the shore should also, [illegible] [illegible] [illegible], be [illegible] [illegible], and [illegible] [illegible] possible representation [illegible] [illegible] would be [illegible]. [illegible] [illegible] [illegible] [illegible] —

10

Contours

[illegible]

[illegible]

a flat surface [illegible]

The [illegible] slope [illegible]

[illegible]

[illegible]

The [illegible] a slope of [illegible]

[illegible] contours [illegible]

there is a slope [illegible]

[illegible] flat [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

ontours [illegible] [illegible] and [illegible] [illegible] [illegible]
than five [illegible] [illegible] [illegible] [illegible]
question.

These methods [illegible] [illegible] [illegible] repeated in drawing a circle [illegible] [illegible] [illegible] and [illegible] [illegible] [illegible] [illegible] for topographical [illegible] [illegible] the system of graphic representation by the successive [illegible] of [illegible] [illegible] horizontal [illegible], invented by [illegible] of [illegible] toward the end of the last century, as at present employed in the Coast Survey, gives the nearest approximation to nature which has yet been devised, and when faithfully executed, [illegible] [illegible] [illegible]

12

tours

[illegible]

[illegible]

Contours or Horizontals [illegible]

are the outlines of horizontal sections

formed at different elevations, and

having equal intervals. Their use is

vertically equi-distant and parallel to

the plane of projection or map, upon

which they are traced in true form and

true relatively to each other and

to the scale of the map [illegible]

scale of the map [illegible]

[illegible] the same horizontal [illegible]

intersection of a horizontal plane

with the surface of the ground.

Practical [illegible]

[illegible]

1.3

ontours. [illegible] [illegible] [illegible] [illegible] [illegible] of [illegible] elevations [illegible] which is employed to [illegible] the elevation [illegible] the [illegible] [illegible].

It must never be [illegible] natural [illegible] of the [illegible] elevation or profile of a hill [illegible] so much as they can be [illegible] with [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] further field measurements.

A profile of a hill is the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

14

[illegible] the hill [illegible] [illegible] [illegible].

The Projection V (diagram Fig. 2) [illegible] the projection of [illegible] [illegible] [illegible] [illegible] plane perpendicular to the [illegible] [illegible] plane [illegible] [illegible] the [illegible] [illegible] [illegible] vertical projection of the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] part parallel lines upon the [illegible] [illegible] [illegible] heights, [illegible] of the hill of 20 feet and the bottom [illegible] intermediate lines x y y [illegible]. The projection of a plane is a [illegible] line, and if we suppose the plane V to be in its normal position [illegible] angles [illegible] extending through the centre of the plane [illegible] [illegible]

[illegible]

15

ntours

line A B [illegible] [illegible] horizontal [illegible] of the

Now [illegible] [illegible] the projections on the

plane V we have the projections of various

specified points of that plane, and the

elevation of the vertical ordinates of these

points above the horizontal plane. [illegible]

select for this purpose the points p p p,

where the profile is cut by the successive

foot horizontal planes we shall carry them

on plane H the projected points p p p

to line A B and there erect [illegible]

and upon that line the projections [illegible]

points of the points p p p. [illegible]

after carrying out this [illegible] [illegible]

having the projections of an [illegible]

number of points with vertical [illegible]

[illegible] [illegible] [illegible] [illegible] [illegible]

Contours

[illegible] [illegible] [illegible]

or [illegible] [illegible] upon the plane of the

horizontal projection or plan of [illegible] the

points a b c [illegible] perpendicular [illegible]

the lines of contour & [illegible] [illegible]

and from the horizontal projection [illegible]

perpendiculars [illegible] & [illegible] [illegible]

required [illegible] of profile & [illegible]

[illegible] in same direction.

[illegible] [illegible] [illegible]

To show the diagram it will [illegible] [illegible]

[illegible] for a full understanding of [illegible]

[illegible] a [illegible] [illegible] [illegible] [illegible]

[illegible] upon the profile [illegible] [illegible]

[illegible] upon the map [illegible] [illegible]

[illegible] [illegible] and [illegible] [illegible]

[illegible]

ntours. b, b, b, show the [illegible] of [illegible] d the [illegible] of [illegible] [illegible] at the perpendicular face of the bottom of upon the bottom. This [illegible] [illegible] when [illegible] of different heights [illegible] upon a topographical plan. D D are depressions in the face of the [illegible] represented on the profile by d, d, [illegible] a trench or dry broken gully, or a water course.

It will be seen that if we were [illegible] suppose the water to rise to a height of 20 feet above the high water line a b of the profile, the 20 feet curve upon the [illegible] would then become the shore line [illegible] the depression D would fill up with [illegible] [illegible] to rise to a height

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ntours. of 30 feet, the [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
would become very [illegible] [illegible] [illegible]

Horizontal curves are drawn on
the map with the eye after having ob[illegible]
the heights by means of which their
relative are fixed by the measurements of
vertical angles with the use of the [illegible]
or in detailed or special surveys, with the [illegible]
When the slope is regular and sharply
steep, the tracing of these is attended
with but little difficulty; but when the
ile is very gradual [illegible] [illegible] [illegible]
zontal distances between the [illegible]
even when the rise is [illegible]
[illegible] [illegible] the drawing is correct.

M

ours. broken, or thrown into zig-zag or irregular-
ly shaped knolls and depressions, pre-
senting an intricate and confused
variation of surface, the correct repre-
sentation is, at times, very perplexing.

As in some instances,
owing to the smallness of the area
to be measured, the vertical arc
cannot be relied upon for close
determination of heights, and as it is
evident that the nearer to a level a country
is, the nearer it is necessary to obtain
the exact elevation for the location
of the Contour, recourse to the level
is indispensable. With the recorder
the observations for elevation are
really of too [illegible], and he should
constantly bear this in mind
while at work, as well as the necessity

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Contours. for [illegible] purposes and [illegible] for
of operations in [illegible] particularly, [illegible]
will serve a useful purpose.

When triangulation points are
occupied, a position is determined by
the Plane Table preliminary to [illegible]
[illegible] in fact whenever any stations
are occupied in [illegible] or [illegible] and
those whose height may be of any
[illegible] for running the contours in the
immediate vicinity, and points of
use in ascertaining other heights, their
elevations should be taken as well as
those of such other prominent points
or objects as may be conveniently
seen thence. These [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible]

21.

ontinue [illegible] point of reference for [illegible] [illegible]ination of height [illegible] [illegible] determining [illegible] [illegible].

It is well also to [illegible] [illegible] for heights as often as possible, or from the plane of reference to [illegible] [illegible] which such advantage should be taken whenever it presents itself, of [illegible] the [illegible] [illegible] [illegible] detail, [illegible] any detached openings which may present themselves, and also upon [illegible] any other natural or artificial [illegible] when the [illegible] of the barometer [illegible].

When the heights of [illegible] points have been taken by [illegible] [illegible] [illegible] [illegible] [illegible] have been determined by [illegible] [illegible]

ours. [illegible] should be used as often as possible as points of reference.

2. [illegible] are [illegible] especially the determination from accessible points, of both the positions and heights of objects upon them, such as trees, rocks, stumps ~~&c.~~ etc, from which the positions and [illegible] of the contours can be determined, should be sought for, and, in thick forests, the roads, paths, or the [illegible] of streams may be found available for the use of either the vertical arc or level.

Under certain conditions, as those of densely wooded heights and vales, inaccessible [illegible] ledges and bluffs ~~&c.~~ etc., the operations of the surveyor are

23.

ntours.

[illegible] [illegible] [illegible] upon the eye alone. Upon ground of other means of travel, and should be avoided as much as possible, and the preceding [illegible] [illegible] proper every course should be represented in the field for heights, and in all [illegible] great care and discretion should be used. Success in this respect depends upon so training the eye as to be able to carry out a line of the same level over an extended and diversified area, after having lost sight of the point of departure &c; and also so as to judge by inspection of the difference of level between points of considerable difference of elevation. This is a difficult

Contours.

between contours being measured and differ-
ence in the slope of the [illegible]
of the ground changes with every [illegible]
and the eye reads [illegible]
which might [illegible] to the change in
[illegible].
Thus in Gettysburgh and other [illegible]
consult the contoured [illegible] for the
judgment of heights and distances
they measured.

It is customary to represent on
the usual Coast Survey sheets [illegible]
of 20 feet, but occasionally [illegible]
marked accidents of ground [illegible]
as [illegible]
[illegible]
[illegible]

3.

tours. [illegible] application in connection with [illegible] ceeding steepness of the descent, giving rise to a liability of [illegible] and confusion. The capability of representation in this respect depends, then, very much on the general slope and abruptness of the hills, as upon very steep the larger the scale of the map the greater the number of curves which can be shown, as in the French Survey of Paris where equidistant horizontal Contours are drawn at every two metres of elevation.

Contours should be filled in from each station while carrying on the general survey, [illegible] to ascertain [illegible]

Contours. For proper sketching & delineating features of ground, especially such as surrounding each, reference should be had to the contours and perspective drawing of the [illegible] on the map. Most of these, where the [illegible] is at and above from the station, will generally have no contours of [illegible] such as will can be recorded with [illegible] facility. When the [illegible] is at a station whose elevation has been accurately determined, lines should be taken to points of equal height in all directions and marked to that effect, subsequent observations giving their positions. It will be found of great assistance in drawing contours and in sketch.

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Contours

With regard to the method of putting in contours from the plane [illegible] it depends on one's own opinion [illegible] some preferring one course some another, but it makes but little difference if the starting point be correct. Sketches of the sections should be specially made [illegible] on [illegible] the circumstances of the [illegible] topography should be considered; and they should be worked together for the best advantage so as to carry on both simultaneously. It frequently happens that a piece of work is done on one part of a sheet and then it becomes necessary to work in another, in which case the point where heights are determined, serves as a point, or [illegible]

Contours

not to cross the drawing. When it [illegible] as often happens, [illegible] [illegible] on a separate drawing [illegible] place. [illegible] Elevations having not been taken for a long time, then the importance of [illegible] [illegible] upon some fixed benchmark [illegible].

When this is impossible [illegible] time occurs in the filling in of topography on sheets [illegible] [illegible] locality and the character is [illegible] before to the work. Frequently [illegible] very short sights and there is no [illegible] to come out upon, or when the work closes on the exterior edge of the work the use of the level in this manner [illegible] [illegible] [illegible] considerable time [illegible] [illegible].

Contours.

The [illegible] as to heights of natural features, [illegible] [illegible] or rocks, boulders, rocks, etc., [illegible] assistance in Contouring should not be neglected.

When the Contours pass any very remarkable accident of ground, as a prominent spur or indentation, on general field maps of this scale, a slight deviation above or below the true plane is admissible, although it is preferable to represent it by the introduction of the auxiliary curves, as shown in the Diagram. It is very desirable that all features within the 20 feet curves, such as breaks in the ground, hollows, hillocks, knolls, etc., which cannot be legitimately

Contours

[illegible] the [illegible] [illegible] shown by thickness of [illegible] When the rocks have a [illegible] position or strike, dip or outcrop their true sh should be indicated.

It may happen that at certain points certain small features which are unimportant in themselves would interfere with the development of the general form of the contours & [illegible] [illegible] may tend to produce confusion, these are best omitted, but this omission should be performed only with the practised hand.

It is a dangerous procedure to give latitude in this respect to a [illegible]

31.

ntours

When there [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] contours [illegible] [illegible] [illegible] [illegible] [illegible] on a scale of [illegible], it should [illegible] be [illegible] or [illegible] figures [illegible] and all [illegible] should [illegible] [illegible] [illegible] follow the downward flow of water or [illegible].

Depressions of the ground in the midst of level tracts or upon tops or slopes of hills, unless occupied by ponds or marsh, should be marked with the letter D on the field map, and [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

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Contours. interpolated, when the intervals are considerable.

The altitude of summits of hills should be marked in figures, when the altitude is a remarkable feature of the scene.

In working for heights in connection with the alidade the Plane Table is carefully levelled and firmly clamped, the telescope is directed toward the point of observation and moved until the cross hairs are on the same

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ntours. vertical [illegible] on the [illegible] height. The telescope is then clamped by means of the screw at the top of the [illegible] of the vertical arc, [illegible] the central [illegible] at or near their intersection are brought to cover the observed point by means of the tangent screw attached to the vertical arc. The angle is then read, the distance between the required point and the observed point measured on the map and the height is taken from the table which is appended.

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Contours

C[illegible]

Observations for Height

[illegible] [illegible] [illegible] [illegible] Station 1.

Stations Obserd.	Obsrd. Angles	Distance in Metres.	Relat. Height in feet of P.T. Stat.	Ht. of Obs. Station in feet	Height of Plane Table in feet.	Corrd. Heights of Ground in feet.
Shore Signal. ([illegible])	1° 57'	1750	+197.4	00	4	193.2
Smith's Hill. ([illegible])	0° 02'	940	− 2.6	201.8	"	19[illegible]
Black Rock. ([illegible])	2° 13'	539	+68.7	126.9	"	195.6

Mean Height of Station = 194.8

Detail of Use of Table of Height.

Shore Signal.

1° 50' for 1700. metres = 179.00 feet

" " " 50. " = 0.1 of 500 metres = 5.[illegible] "

" " " 0. " = 0.01 " 600 " = .1[illegible] "

0 07' " 1700. " = 12.1 "

" " " 50. " = .3[illegible] "

" " " 0. " = .0[illegible] "

Total. 197.37.

35.

Contours.

In these instruments the plates at both [illegible] [illegible] [illegible] upon either horizontal and the [illegible] adjusted. The adjustment [illegible] found invariably subject to [illegible] rough usage at the stations [illegible] [illegible] of the instrument [illegible] [illegible] frequently examined.

A material advantage in the attachment of a longitudinal level to the [illegible] would be found in the facility by which the instrument could then be used as a level in following out lines of equal elevation, and would be particularly serviceable in [illegible] [illegible] contours.

ontours

A formula for [illegible] tion of heights which gives a more accurate [illegible] table of heights will be found in appendix.

When it is desirable the use of a surveyor's level is employed the determination of the position of the contours by the Plane Table or the sketch is all that is necessary and the contours can be easily traced.

Barometric heights are admissible for approximate purposes in reconnaissance where a general approximate idea of heights is all that is required. A table accompanying [illegible] is given for approximate [illegible]

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Contours.

evation from observations of the mercurial barometer, and also of the aneroid barometer, but in using the latter instrument in ordinary reconnaissance it will suffice to allow 92 feet of elevation for every 0.1 of an inch fall of the index. This allowance is for a mean temperature of the two stations of 55° Fahr. and will vary with the temperature.

Leslie's formula simple and easily remembered is a good approximation below 2.500 feet and convenient for aneroid observations, viz: as the sum of the two readings is to their difference, so is 55.000 feet to the ascent required, or $55.000 \times \frac{B-b}{B+b}$ = height in feet. B being the upper and b the lower reading of

ntours. the correction here is also for a mean temperature of 55° and a correction must be made for each degree below.

A very convenient instrument for a tolerably close location of contours when carefully employed is Locke's hand-level, which can be used by one person without assistance and can be readily carried in the pocket, it being requisite only to know the height of the eye from the ground and for the observer to stand upright over each point of observation, or to hold the level at a constant height upon a marked staff.

It must sometimes [illegible]

[illegible]

39.

ntours. for a base line, or for some other special purpose, to produce a profile, or elevation (V. Diagram No. 12) of a specified section of ground, and as this is constructed by means of a projection according to any desired scale upon a plane supposed to be placed rectangularly to the horizontal plane of projection or map, as before described, it cannot be placed in its correct position upon the chart itself, but requires a separate drawing. So when more than one profile of the same piece of ground is desired, in different directions, as many planes of projection are requisite as there are profiles.— Usually the elevation is obtained by

leveling in a direct line acroſs the section required to be plotted, and then the drawing is made according to any required scale, the different Contours being marked by parallel lines at certain distances; but as has already been stated, it can be constructed directly from the map itself when the latter has been carefully executed on a sufficiently large scale, and when it presents the number of curves neceſsary to answer the requirements of the profile which is needed. —

ontours. Formula for the difference in levels with the Plane Table and vertical arc.

Δh = difference in feet, K = distance in feet.
A = angle of elevation in seconds.

$$\Delta h = 0.0000159\,K A + 0.000000022\,K^2$$
[5.202] [3.344]

Example

Distance K = 16380 ft log. K 4.214 log. K² 8.428
A = 0°6'33" = 393" log. A 2.594 const. 3.344
const. 5.202 1.772
first term 102 2.010
second " 59
Δh = 161 feet

By [illegible] Δh = [illegible]

42.

Contours

[illegible] [illegible] [illegible] [illegible] which [illegible] distance of [illegible] [illegible] and will not differ [illegible] more than a foot from the result of a [illegible] [illegible]; in fact it will keep [illegible] [illegible] of [illegible] of the [illegible] tion itself.

43.

[illegible]

ontours. [illegible]

[illegible] at the station, the temperature of the [illegible]

Barometer inches	0.1 inch corresponds to	Barometer inches	0.1 inch corresponds to
28.5		29.6	88.4 feet
.6	91.5 feet	.7	88.1 "
.7	91.2 "	.8	87.8 "
.8	90.9 "	.9	87.6 "
.9	90.6 "	30.0	87.2 "
29.0	90.3 "	.1	86.9 "
.1	89.9 "	.2	86.7 "
.2	89.6 "	.3	86.4 "
.3	89.3 "	.4	86.1 "
.4	89.1 "	.5	85.8 "
.5	88.7 "		"

Contours.

Correction for Difference of Temperature

Degrees Fahr.	Feet	Degrees Fahr.	Feet.
1°	2.3	12°	28.1
2°	4.7	13°	30.4
3°	7.0	14°	32.8
4°	9.4	15°	35.1
5°	11.7		
6°	14.0		
7°	16.4		
8°	18.7		
9°	21.1		
10°	23.4		
11°	25.8		

Negative when the Temperature at upper station is lowest.

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Contours

For an aneroid barometer the correction for temperature does not apply; the upper reading must be reduced to the temperature of the lower reading, when the temperature correction for the instrument has been ascertained, (which must be done by experiment,) and the difference of height can then be taken from the first table.

In an aneroid barometer the indications for the same point will be increased by an increase of temperature, owing to the expansion and consequent greater flexibility of the elastic surface of the vacuum vessel.

46.

Contours.

Example.

Suppose Bar. at lower station 29.8 in. Temp. 60°

" " upper " 29.4 " " 46

0.4 14°

Difference in elevation 353 feet, correction 35

Corrected " " " = 390 feet.

Example for an Aneroid.

Temp. correction — 0.005 for 1° Fahr.

Reading at lower station 30.00, temp. 70° (Inches)

" " upper " 29.18 " 66°

correction for 4° Fahr. 0.02

corrected reading at upper station 29.20

Difference 0.80 corresponds to 8 × 89 = 712 feet.

12.

Chain.

1

Chain— [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] been furnished [illegible] [illegible] [illegible] [illegible] desirable [illegible] [illegible] [illegible] measurement of distances [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] the [illegible] [illegible] the accumulated [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] give a short description of the one employed in the Coast Survey, and reasons for its [illegible] use.

The chain of the [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

2

uain.

[illegible]

3.

Chain.

resulting from this is questionable, as the rupture almost invariably occurs at the joints, and multiplying them of course increases the liability to breakage; besides, the "kinking", or tendency to overlap, or double, is also increased in proportion to the number of joints. On the other hand it may be said that the bending of the links is decreased in proportion to their shortness.

At each extremity of the Chain is a large ring which slips over ~~the~~ a staff, held in the hand of the chainman, and rests upon a projecting rim of the

4

Chain

position [illegible] at the base. The centre of these rings at the ends of the extended Chain are the extremities of a line of twenty metres and are the points at which the pins should be inserted in the chaining.

As the strain constantly be exerted upon the Chain in straightening it must finally lengthen it by the giving of the rings so as it must [illegible] [illegible] be shortened when the links are bent by being drawn over fences [illegible] or other unyielding obstructions. It is well to test it occasionally by a careful veri-

5

pairs

[illegible] is more applicable than [illegible] when chains [illegible] have been [illegible] suddenly upon being [illegible] released from a [illegible] in use. In fact before beginning his work the Surveyor should always make sure that his chain is mathematically exact by comparison with a standard and [illegible] at least have a wall or fence measured and [illegible] for occasional reference.

Adjusting screws are attached to the terminal ends of some of the chains by which any error of length can be corrected.

6

Chain.

but when this is not the case, the allowance for differences in length may be made when we are laying out lines or in cases of long distances, it is sufficiently great to be necessary.

If a line of any length has been measured by an incorrect Chain, resulting in a disagreement with the intersecting lines at a point determined by the Chain, the error may be ascertained as follows:–

As the length of the Chain
Is to the true length of the standard
So is the length of the measured line
To the true length of the line.

7

Chain

Each Chain is accompanied with ten pins made of iron of sufficient strength for carrying them. They are also made of steel wire about 18 inches long, pointed at one end and bent into a ring at the other. When in the process of chaining the pins have all been placed down & taken up they compose a "tally" of ten chains or two hundred (200) metres.

It is well to attach white cotton or red flannel rags to the ring of each pin that the rear chainman may distinguish it more readily in high grass, weeds, bushes etc, and also as

Chain.

the ends of each 5th and 15 [illegible] links in the Chain for facility in counting. These tags should be changed as they become worn.

In the operation of chaining the "forward" and "back" chainmen are needed and care should be exercised in the selection of intelligent men for this purpose, since it is often upon the precision of their work that the correctness of the survey in a great measure depends, and it is not always convenient nor always possible for an assistant to accompany them. The better man of the two should be placed at

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Chain

the rear man of the chain, as he is the more responsible, and the forward man should implicitly obey his instructions. In all important places however, and as closely settled districts, at all such times, the measurement of those lines or distances upon which any thing of much may depend, an aid should go with the chain, and check the records of the men.

The line to be chained be given by the chief of survey or his aid and before starting any details should be strictly regarded:

1st to be assured of the exact agreement of the length of

10.

Chain. the Chain with the standard measure, 2nd to keep the alignment, 3rd to keep the Chain taut, 4th to keep it horizontal, 5th to place the pins exactly in the hole made by the staff, and 6th accuracy in counting.

Being ready to start, the forward man passes the end ring over his staff and grasping the latter in his right hand with the triangle containing the ten pins in his left, or in a belt about his waist, he draws out the Chain on the line in the direction of the forward signal. The rear chainman holds the other staff, also

11.

Chain.

passed through the rings at the other end of the Chain, in his right hand, the point of the iron shoe being held firmly in the ground, exactly at the starting point or station, and when fully extended, he examines the Chain carefully to see that there are no "kinks" at the junction of the links and no bends in the links themselves. He then resumes his place at the station, and holding the staff firmly and perpendicularly in its place with his eye directly over the point, he sights towards the forward signal. By a motion to the right or left with his left hand he indi-

12.

Chain. cates to the forward man where to place his staff "in line" so that it shall cover the forward signal or object to be chained to.

The forward man stretches the Chain taut, shaking it upon the ground with an undulating movement, while the rear man, by placing his right foot in front of the base of the staff, keeps it in its place. Sometimes a strong iron pin is inserted through the staff transversely and just above and resting upon the upper edge of the iron shoe to serve as a bearing for the foot in order to press the point of the staff in the

13.

Chain.

ground and hold the Chain firmly while being hauled from the other end. This is considered less awkward and more secure than placing the foot in front of the staff; but some object to its use on account of the ease with which it becomes bent or broken, and from the fact that it weakens the staff at the point of the greatest strain.

As soon as the forward staff is in its correct position the rear chainman cries "Stick", and the other places a pin upright in the centre of the hole made by the point of his staff, and replies "Stuck". In chaining any line,

14.

Chain.

however long this, together with the occasional cry of "Hold" and "Tally," referred to hereafter, is all the conversation that need occur between the two men, and all other calls, such as "right," "left," "halt", "haul taut," and others which are frequently used, are sometimes confusing; tending to distract the men from correct counting, and entirely unnecessary when the chainmen understand their duty.

When, from the hardness of the soil, or from any other cause, it is impossible to stick the pin in the ground, a mark of two cross lines intersecting at

15.

Chain. the proper point, or a hole beaten in with the point of the staff should be made, and the pin so placed over it, with the ring surrounding the point, as to lie lengthwise, in the direction of the line, that the Chain in moving may not alter its position. The more quietly the chaining is done the more accurate is the result.

The rear man, keeping the staff in his hand, as soon as he hears the cry "Stuck!," and not till then, should release the point from the ground and the other, casting his Chain a little aside

16.

Chain.

to avoid displacing the pins, moves directly forward toward the object in view.

The rear man should learn to estimate the length of the Chain by the number of his paces so that, where, on account of high grass, or other obstacles, the locality of the pin is uncertain, he may thus be able the more readily to find it. As he approaches the pin, and just before reaching it, he calls out "Hold." He should never wait till he is fully up to the point and thrust his staff suddenly down at the pin, as this arrests the forward man

17.
Chain.

too abruptly, is very fatiguing to him, and is liable to snap the Chain. With some officers the following is a favorite method. The rear man indicates his near approach to the pin by gently retarding the Chain. The forward man then faces about, and backs with the Chain until the point of the staff is carried two or three inches beyond the pin; it is then drawn back again to its proper position. In this way a "kink," which is quite liable to occur if the rear staff has to be advanced at all towards the pin after the Chain is stop-

18.

Chain.

ped, is avoided.

The forward man, when the rear one has his staff upright at the pin, gets approximately into line by ranging the rear staff with the back signal or station, and in this way, with a little practice, he can keep the line exactly without further guidance, and indeed in some cases, where the forward signal is lost sight of, it is the only means of keeping the line. The rear chainman, however, should never fail to look at his alignment when the signal is in sight, as the responsibility of its correctness should always rest with him.

19.
Chain.

When the forward pin is down, and "Stuck" has been called, again, the rear man takes up his pin with the left hand, and the chaining proceeds as before.

The tenth and last pin being placed, the forward man goes on another Chain length, and after getting in position cries out "Tally!" The rear chainman then releases the Chain from the staff, goes to the former, gives him nine (9) pins, retaining one, which he places in the ground at the point of the forward staff, and remains there until the rear end of the Chain has been drawn

20.

Chain.

up to him. Both men count the pins at each "Tally" to make sure that none are lost.

The station or end of the line being reached by the forward man he continues on till the rear man arrives at the last pin which has been placed in the ground;- the links between this pin and the station are then counted; and both chainmen note the distance in tallies, pins and links, not attempting to count the metres, leaving that for the Aid or Assistant.

Every tally represents ten pins or chains of twenty metres each, to which the pins held by

21.

Chain. the rear man should be added, and also the extra links between the last pin and the station; and when necessary the parts of a link.

Example:-

3 tallies = 600 metres; 8 pins = 160 metres; 13 links = 13 metres; total 773 metres.

Some chainmen prefer to keep the account of tallies by transferring pebbles from one pocket to another, cutting notches on a stick, and by other methods; but it is better, on the whole, either to trust to the memories of both men as it begets caution and

99

hain.

attention to such work, it is found necessary to keep the record in a special book prepared for the purpose.

When chaining is done in connection with the Plane table, when the station is reached the chain is drawn sufficiently beyond to be clear of the table & be out of the way, so that if more chaining is contemplated it does not have to pass the legs of the instrument.

With the class of persons usually employed as chainmen in the Coast Survey parties it has been found safe and convenient [illegible] in both instances.

23.

Chain. in the absence of an Aid to have the rear man keep a Chain book in which he notes all the crossings of high and low water, intersections of brooks, fences, roads, ~~ect~~ etc, with rectangular offsets to all reasonably accessible points on either hand, including bottom and tops of slopes, the record of tallies, and such other matters as may be needed, and may serve to assure accuracy in case of unfavorable intersections.

It is the habit with some, in obtaining short distances, to comparatively un-important objects to trust to pacing, and practice

24.

Chain

enables one to ascertain thus the distances sufficiently close for plotting on a $\frac{1}{10.000}$ scale; but these distances should never be ~~very~~ great, and the topographer should be well assured of the accuracy of the pace. The use of the ~~stadium~~ telemeter however may take the place of this method.

All distances to objects on either side of the Chain line should be taken by offsets at right angles to it, and the book of the Aid should ~~be held~~, as far as possible, be held so that the line drawn as his guide in sketching should be in the same direction as the

25

Chain

[illegible] [illegible] may [illegible] the enable them to know the [illegible] their true relative positions.

Where a long line is to be measured over a rolling or uneven country, or where there are numerous obstructions of any kind to be passed which may, to a certain extent, intercept the view, it is well for both men to note, before starting, or at any time during the measuring of the line, such marked or elevated objects which may be exactly in range with the forward and back signals, and which may continue to serve good stead when the signals

26.

Chain. themselves are obscured.

Should there be encountered upon the line any pond, ditch, creek, patch of marsh, or other impassable object, less than 20 metres in width, which can be spanned, the distance should be taken to the edge of the bank and the Chain either stretched across sufficiently to make up the rest of the full Chain, or the pin on the margin used as a new starting point, - care being observed in counting.

All distances should be measured horizontally, as when chaining upon an inclination a

27.
Chain.

line is made too long in the proportion of the hypotheneuse to the base.

Upon slight or gradual slopes, the up-hill end of the Chain should be held close to the ground, and the other end raised until it is level, keeping it taut, carefully in line, and plumb over the correct point by means of the staff, or by dropping a pin or stone; a third person, standing on one side, can judge of its horizontality. If the hill be very steep, parts of a Chain can be used and the links counted successively. In this case the

28.

Chain.

whole Chain should be stretched out in line, and in descending the rear end held to the ground, and as many links forward as the slope will permit, raised to a level with it, a pin being dropped perpendicularly from the forward end. The rear man should then come forward and again place his end of the Chain upon the ground at the pin, and another number of links held up and added to the former number, and so on. In chaining up hill the operation is reversed. In other words it is the measurement of the widths of a series

hain

of horizontal distances measuring from each in their each other which sum form the base of the triangle or the distance required.

Some surveyors prefer to employ parts of the Chain successively until the whole is used out without counting the links of each portion under the idea that there is less liability to error, but this depends upon the care of the operator, and it is optional.

Where great accuracy is necessary the length of a gradual slope may be measured and the angle of inclination taken.

30

nain with the vertical arc with accuracy, or with an ordinary [illegible] instrument, and the measurement made reduced to the horizon by means of the following formula:—

Let y be the length of the line measured upon the slope, α the angle of inclination and x the length reduced to the horizon, then

$$x = y \cos \alpha$$

31

The effects of [illegible] may be computed by the formula $y - y = 2y \sin^2$ [illegible]

On very large scales where parts of a metre are perceptible, Payer's rule, consisting of a narrow steel ribbon, which can be marked for several distances has been employed to advantage.

32.

Chain. It is convenient also for rapid reconnaissance in military surveys, and has been used under fire almost at double quick. Under these circumstances, three men were employed, the usual back and forward chainmen, with another to stand by the pins when stuck until about half the Chain had passed, then, by pointing, to indicate the position of the pin to the back chainman, and run forward in time to find, without difficulty, the forward pin, and also to change the pins at each tally. This tape will not stand as rough handling as the Chain, and

38

hain

cannot be repaired in the field when broken while the latter can lose one or more of its links and still be of service. Where it is broken at a moderate distance from either extremity it can be used by allowing for the difference, but its constant liability to this accident renders it objectionable when it is to be subject to much strain out of the direction of a straight line, and the easy obliteration of the marks inscribed upon it by attrition has also been found a source of difficulty. The latter however might be remedied, perhaps, in the manufacture.

34.

Chain.

All chaining measurements should be [illegible] a very carefully compared [illegible] instrument.

These [illegible] showing the remarkable accuracy with which the chain can be employed [illegible] tables could be given from the reports of the officers of the Coast Survey, but it must be remembered that it is to be used when other means are impracticable, and it is only necessary to state that a close adherence to the six rules already given will produce satisfactory results.

1.3.

Telemeter

1

lemeter

The inconveniences [illegible] of the determination [illegible] [illegible] employment of the chain, [illegible] [illegible] are the necessity of frequent [illegible] for correct distances upon the [illegible] men, who through carelessness or incapacity are liable to err, the number of persons required, the time consumed in the management and the impediments to be found in the features of some localities or country, another instrument styled the Stadium or Telemeter has been advantageously introduced in the topographical work of the Coast Survey.

Various names have

lemeter.

Been variously [illegible] description, various others "Distance Rod" "Distance Measurer" "Telemeter" "Scale Rod" "Line Metre" etc. and although objectionable as not expressing or giving a correct idea of its use it seemed best to preserve the name given to it when originally brought into notice that of the Stadium; The name Telemeter however appears to meet with most favor and is therefore used in these pages.

The use of the micrometer attachment to the telescope and a graduated staff for the measurement of distances was first practised under the name of Stadia (Italian Scale) or Stadia (Rods) by an Italian engineer about half a century ago.

3

licrometer

[illegible] the [illegible]

[illegible] of the [illegible]

Huygens suggested the use of an

instrument for the measurement of

distances in [illegible] not [illegible]

by himself but at the same time

[illegible] the same, probably [illegible]

[illegible] merely upon the [illegible]

About the same time the

a [illegible] British astronomer [illegible]

[illegible]. These two instru-

were designed to produce the same

result with the operation [illegible]

[illegible] to each other [illegible]

the [illegible]

Telemeter [illegible] [illegible] [illegible] [illegible]
upon a [illegible] [illegible] distance [illegible]
the [illegible] [illegible] [illegible]
[illegible] of [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] a [illegible] [illegible]
face of the [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible], and [illegible]
[illegible] [illegible] [illegible] [illegible]
by the staff [illegible] upon [illegible]
the distance.

Other devices [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]

5.

lemeter

through the centre and known as the Telemeter. The cross hairs of the telescope being placed vertically. But it seems that instruments of this class were at first generally regarded by scientific men as merely ingenious inventions, and not as valuable in most respects as the ordinary method of chaining, the filling in of details forming a principal operation. From the experience of the use by the officers of the Coast Survey, however, it has been satisfactorily ascertained that the rapidity with which the details of a survey can be determined, and sketched, is doubled

6.

…lemeter: It [illegible] necessary to be employed that whatever errors made occur rest with the observer only, and the facility in using it in places where the use of the chain is impracticable or at best difficult render the Telemeter a very important acquisition. It is not considered that it will ever entirely supersede the chain as a measuring instrument, but it is undoubtedly a reliable and useful substitute under certain conditions, and in certain sections and there are some who think that for all topographical surveys, beginning with a pur[illegible]

imeter [illegible] made [illegible] [illegible] subsequent number it
he so speaks [illegible] that "perhaps the
"but that the art of topography had
"no existence before its use."

The Telemeter as used in the Coast Survey is simply a scale of equal parts painted upon a wooden rod about 11 feet long, 5 inches wide, and 1½ inches thick so graduated that the number of divisions upon it as seen between the upper and lower horizontal wires of the telescope, and embraced by the visual angle formed by the produced imaginary rays proceeding from the eye through the wires to the rod, be equal to the number of units in the

elemeter. distance between the object glass & point of divergence of the visual rays and the centre of the rod held at right angles to the line of sight.

In all cases the Telemeter should be graduated experimentally for the particular instrument and eye of the observer who has it in use.

The horizontal wires in the diaphragm of the telescope should be accurately adjusted, and the divisions of the Telemeter made to correspond in length with the distance intercepted between the upper and lower wires of the telescope at a carefully measured distance and then divided into the [illegible] equal

elemeter parts or less are read on the [illegible] were measured.

For convenience of transportation it can be hinged in the middle and secured in the [illegible] when in use by a sliding [illegible] as it is necessary, when observing, that it should be held accurately [illegible] right angles to the line of sight, a brass movable bar, with sights or groove upon its upper edge, should be fixed upon the side of the rod at a convenient height for the eye of the rodman and which when in position, will be perpendicular to the plane of the Telemeter and directly in the line of sight.

Telemeter of the Telescope.

Now if a rod be placed perpendicularly to the line of sight at a distance of 50 metres, and a space of one foot be subtended on the rod between the wires, and then the rod be removed to a distance of 150 metres, 18 inches will be subtended, and at 210 metres, 2 feet, and so on; because according to a law of optics "the size of the "image formed at the focus of the "object glass is inversely as the dis"tance of the object from the instrument."

The employment of the Telemeter amounts in fact to triangulating vertically with a

11.

meter.

[illegible] [illegible] might [illegible] [illegible] [illegible]
five sides of the triangle [illegible] [illegible]
and the [illegible] [illegible] [illegible] [illegible]
distance between the [illegible] [illegible]
which might [illegible] the [illegible] [illegible]
the triangle is a [illegible] [illegible] [illegible]
single formula [illegible] [illegible] [illegible]
from the use of the [illegible] [illegible]
[illegible] [illegible] [illegible] in the [illegible] [illegible]
are affected by a [illegible] [illegible]
the [illegible] the [illegible] [illegible]
to [illegible] the triangle formula [illegible] [illegible]
[illegible] of the [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] of [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] in [illegible].

Telemeter

[illegible] [illegible] [illegible] [illegible]
[illegible] depends upon the [illegible]
of the readings and the accuracy [illegible]
which can be [illegible] both [illegible]
to the line of sight.

With reasonable care the error of reading should not exceed [illegible] on the greatest distance [illegible] on the rod. With the [illegible] [illegible] [illegible], and the reading the rod [illegible] to a [illegible] [illegible] the greatest distance [illegible] [illegible] [illegible] [illegible] can be [illegible] practically correct. There is no [illegible] error at [illegible] [illegible] greater than 20 [illegible] [illegible] [illegible] 200 [illegible] [illegible] [illegible] [illegible]

13.

Telemeter [illegible]

[illegible] insufficient [illegible]

20 meters, but it will [illegible]

[illegible] upon [illegible]

from 15 to 500 meters [illegible]

cannot be used with accuracy for [illegible]

[illegible]

The Telemeter has been

recommended for [illegible]

[illegible] necessary

to determine distances in [illegible]

[illegible] the [illegible] of [illegible]

[illegible] the determination of [illegible]

of [illegible]

[illegible]

the latter [illegible]

396.

limeter

[illegible]

[illegible]

[illegible]

[illegible] in all [illegible]

[illegible] is preferred [illegible]

[illegible] in all cases [illegible]

[illegible] the distance are [illegible]

that the telescope will not [illegible]

the accurate [illegible] of the [illegible]

[illegible] instrument [illegible]

[illegible] a single determination [illegible]

[illegible] horizontal can be [illegible]

[illegible] accurately determined.

For the selection of

the [illegible] the [illegible]

[illegible]

Petrometer: [illegible]

[illegible]

[illegible]

16.

elemeter

Table for [illegible]
Hypotenuse & Base.

Angle	Hypotenuse.				
	metres 100	metres 200	metres 300	metres 400	metres 500
5°	99.62	199.24	298.86	398.48	498.[illegible]
10°	98.48	196.96	295.44	393.92	492.[illegible]
15°	96.59	193.19	289.78	386.37	482.[illegible]
20°	93.97	187.94	281.91	375.88	469.[illegible]
25°	90.63	181.26	271.89	362.52	453.[illegible]
30°	86.60	173.21	259.81	346.41	433.01
35°	81.92	163.83	245.75	327.66	409.58
40°	76.60	153.21	229.81	306.42	383.02
45°	70.71	141.42	212.13	282.84	353.55

11.

Reconnaissance.

Reconnaissance.

[illegible]

a Reconnaissance [illegible] the [illegible]

[illegible] for certain purposes [illegible]

[illegible]

[illegible]. The remainder of

Reconn^{ce} "

accuracy and closeneſs of detail required depends solely upon the object for which the survey is undertaken, and the time and expense allotted to its completion. It is always best, however, to strive for the greatest precision which the circumstances will allow, particularly as the sheet may at some future time become available for other objects than that originally intended.

To the practiced surveyor it is unnecesary to give any rules for his guidance, as his knowledge of the use of the Plane Table and of the requirements of the special work which he is called upon to perform will

nnaissance

[illegible]

[illegible] reconnaissance [illegible]
topographical [illegible] of the [illegible]
[illegible] indispensable information.

The second was less [illegible]
in a feasible manner [illegible]
accurate information which was
suited to the topography of [illegible]
[illegible]

Reconnaissance [illegible]

[illegible]

[illegible] of topographical [illegible]

[illegible]

[illegible] of the [illegible]

[illegible] in the field [illegible]

[illegible] and [illegible]

of [illegible] from the commencement of

the war to the close topographical

[illegible] were [illegible].

Until [illegible]

little was known [illegible]

the [illegible] of the [illegible]

reconnaissance instrument [illegible]

to the [illegible] of all the officers

connaissance. [illegible]
[illegible] to [illegible]
[illegible] the [illegible]
[illegible] affecting [illegible]
[illegible] instrument [illegible]
[illegible]
which have been [illegible]
[illegible] of the [illegible]
different [illegible] for [illegible]
Topographical work has been [illegible]

The [illegible]
[illegible]
[illegible]
[illegible]
the [illegible] Lake.

[illegible]

econnaissance.

for [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
a chain [illegible] of [illegible]
with [illegible] of [illegible]
[illegible] is [illegible].

The [illegible] [illegible]
different kinds of [illegible]
[illegible] [illegible] [illegible]
[illegible] were [illegible] with [illegible]
common 20 metres chain, the [illegible]
have been used for both [illegible]
after considerable [illegible]
[illegible] triangulation [illegible]
[illegible] the [illegible] were [illegible]
two-and-a-half miles [illegible]
[illegible] and the [illegible]
[illegible] of [illegible]

7.
Reconnce.

was but about 15 metres. Many other points of junction indicated this to be the maximum error. In this case the leaves were mostly off the trees, and the hills afforded good points. The sheets covered about 20 square miles each. At Nashville there was a discrepancy of about 10 metres in 2 miles. This would not do ofcourse in finished work, but is very close under the circumstances.

At other times when the character of the country, or the pressure of time did not admit of the measurement of a preliminary base and topographical triangulation, the work was commenced by

8.

Reconn^{ce} ". starting from a single point, and prosecuted by linear measurement with the chain, intersections from the ends of the chained lines being taken to determine objects, which, as the work progreſsed, could also be used as checks upon the chaining. Where circumstances permitted an occasional return with the chain to a back point, either to close a series of lines upon it, or to start afresh was resorted to. This work was generally carried on over roads and the interior filled in by sketching and intersections as far as practicable. Some of the tests in this latter work, where the operations of two officers joined, were

9.

Reconn^{ce}

remarkably close.

A very efficient Reconnaiſsance officer estimates that with the usual number of hands and a good sketcher for aid, in a country of average variety of detail, in which all the houses, prominent barns and out buildings, streams, roads, general outline of woods and approximate curves are to be shown, on a scail of $\frac{1}{10.000}$, an area of between two and three square miles can be filled in daily, with not only sufficient accuracy for military purposes; but so that an accustomed eye "with the map in hand, would not "discover any marked discrepancy."

connaissance, and detailed work, [illegible] [illegible]
not [illegible] in [illegible] [illegible] [illegible]
[illegible] [illegible]. It is probable [illegible]
enough work would [illegible] [illegible]
one half this summer.

The Plane Table was
[illegible] and where [illegible] of [illegible]
has been found advisable to [illegible] [illegible]
main work with the Plane Table and
fill in with the compass, [illegible] [illegible]
which had been accurately [illegible] [illegible]
the entire work is done with the
Plane Table alone. The method now
employed, where these [illegible] [illegible]
[illegible] [illegible] was as follows.
Where the

11

connaissance [illegible] the [illegible] the [illegible]
[illegible] the [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] the [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] of the course. [illegible]
at any important point of the
course are [illegible] and point to
the right and left, [illegible]
[illegible] [illegible] point [illegible]
[illegible], and [illegible] the
and opposite and [illegible]
to the [illegible] [illegible] [illegible]
the [illegible], the [illegible]
of [illegible] being [illegible]
[illegible] for the purpose. [illegible]
[illegible]

onnaissance. [illegible]

as shown on the [illegible]

[illegible] (Plate [illegible]) [illegible]

[illegible]

[illegible] and [illegible] in the

[illegible] of my party [illegible]

[illegible]

The positions of [illegible]

reconnaissance officer are at the

first however of the [illegible]

to mark, the [illegible] of [illegible]

[illegible] flag staff [illegible]

of fortification as well as [illegible]

position that will command [illegible]

could come within the [illegible]

[illegible] and the [illegible]

13.

Reconn^{ce}

of bridges, the character of the roads whether paſsable or impaſsable for the different arms of the service, suitable locations for camps and hospitals, the character of ſtreams, whether fordable or not, and all correlative information should be noted upon the map. All spare time should be employed in obtaining a knowledge of the country, and information should be sought from every available source.

14.

Office Work.

1

ffice Work.

All the drawing of [illegible] physical features of the natural [illegible] the chart should be sketched in the field while they are still [illegible] sketching and plotting in the office from notes unless the country be seen at least for many [illegible] make an effective sketch [illegible] trouble. Where this is unavoidable the sketch should be transferred to the sheet as soon as possible after having been taken while fresh in the mind of the observer where it was made and [illegible] also if possible he should be plotted [illegible] which [illegible]

Office Work [illegible] of the [illegible] may be made
for use of the work, [illegible] as [illegible]
of this portion each [illegible] should
be taken of them either for [illegible]
many details of the [illegible] which
have become [illegible] or [illegible]
[illegible] and that should [illegible]
be [illegible] of [illegible]
to [illegible] the [illegible]
generally at a distance from the
field of operations, the necessity for
this will be obvious. — The pencils of
Faber brands are generally considered to
be best for this purpose, for [illegible]
very hard or very soft lead pencils
should be equally avoided. —

3.

phic Work.

The materials used in inking a finished topographical sheet should be of the very first quality. There are many varieties of indian ink manufactured, some of them inferior and totally unfit to be employed, and the same is true with regard to red ink. Of the former the best is the imported Chinese or Japanese, such as is now furnished from the Coast Survey Office; but even among these there is a necessity for care in selection, good indian ink having a clean fracture, leaving a shining and slightly iridescent surface and a musky odor. It grinds upon a moistened

4.

fice Work.

surface smoothly and without grit, and has a soft and uniform, instead of a granular consistence upon being rubbed between the finger and thumb when nearly dry. Of the latter the best carmine only should be used, as red inks are to be found of every shade of quality good, indifferent and worthless. It is now made in this country fully equal to the French, which was, until recently, the only kind fit for use. Red ink has been objected to from its liability to fade, or to change color, but if the right kind is employed and it is put upon the

map sufficiently boldly, and with a gold or quill pen only, these difficulties will disappear. Pale inks should never be used, the indian ink should be as black as it can be made and preserve its fluidity, and the carmine, unless of a deep rich color with a good body, should be rejected.

Two kinds of drawing pens will be needed, one with a rather blunt 'nib' for heavy lines, and one with a very fine point for the more delicate work. Some prefer Cohen & Co's 'extra commercial' and Gillotts 'No. 303' writing pens, but the writer has found that

6.

ffice Work.

The duties in connection with the [illegible] work and the lithographic [illegible] are a [illegible] [illegible] [illegible] [illegible] of [illegible] [illegible] [illegible] completeness [illegible] [illegible] [illegible] [illegible]. A right line, a [illegible] pen, and a pen for describing very small circles around stations would all be found necessary.

In the inking of a topographical sheet three requisites for a proper observance [illegible] should be borne in mind — accuracy, neatness and uniformity.

7.

ice Work.

The lines and objects should be clean and sharply defined, nothing being left obscure or doubtful, – the paper should be kept unsoiled and erasures avoided as far as possible, and the style and strength of the drawing should be the same throughout. It is an important matter that an easy and natural appearance should be given to the map; for, as before remarked, a mere rigid adherence to conventional signs is not all that is necessary; ~~for~~ while there should be no deviation in this respect, at the same time the draughtsman should

Office Work.

[illegible] [illegible] [illegible] [illegible] is a great difference [illegible] [illegible] the natural topography, [illegible] [illegible] correct sketch of the same [illegible] ground made by different [illegible] one is [illegible] and while [illegible] has a stiff and unnatural [illegible] the other appears [illegible] [illegible] [illegible] [illegible] the impression of [illegible] faithful representation of the [illegible] surveyed.

Office Work should not be commenced until the topography is entirely completed [illegible] [illegible] or partially inked sheet [illegible] [illegible] [illegible] in the field. [illegible]

Office Work. times, for the special examination of old work, or for the insertion of some recent artificial or natural changes, this becomes necessary; but there is always a risk of injuring an inked map by exposure to the weather, or by using it upon a Plane Table.

The inking should commence with the shore lines, high and low water. The high water, or shore line proper should, in all cases, be full and black, the heaviest line on the sheet, and in this, as in all the rest of the ink work, the lines of the survey should be strictly adhered to.

10

ic Work.

The topography as drawn in the field is supposed to be correct when the chart is finished, and no Office amendments or changes are admissible. The low water line is next drawn, not so full as the former, but clear, black and uniform, consisting of a dotted line for sand and mud, and the conventional sign where it is formed by shells, rocks, or coral-reefs.-

Grass upon flats, or shoals covered at high tide, have no distinct continuous line to mark their limits, each being represented in its proper form and within its area by its conventional

11.

fice Work. [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

of the [illegible] but not faintly [illegible]

[illegible]. The thickness of the [illegible]

[illegible] points [illegible]

should be moderately [illegible]

[illegible]

[illegible]

The [illegible] should

[illegible] be inked, slowly and evenly

and then [illegible]

The [illegible] should [illegible]

the [illegible]

12.

ne Work. then should follow the fences and houses. In drawing the latter care must be taken that the corners and angles exhibit a sharp, clear outline, which adds much to the appearance of the map.

The general skeleton of the survey being now completed the contours are drawn with a bold, uniform, plain red line, without break over all the other work, following accurately the full range of level of each of the contours on the sheet.

After this comes the general filling in by conventional signs, - of sand, marsh, grass,

424

13.

Office Work. [illegible] with the [illegible]

Some practice is needed to [illegible]

and with regularity and rapidity [illegible]

should [illegible]

[illegible]

practice. The [illegible]

and the [illegible] of [illegible]

[illegible] should [illegible]

[illegible]

[illegible]

[illegible] The [illegible]

[illegible] (Sketch No.) gives

conventional signs [illegible]

and [illegible] used in the field [illegible].

Office Work.

[illegible] rather difficult [illegible] the working from beginning [illegible] which was followed, and for [illegible] sketches are drawn (Sketch No.) It is expected that every draughtsman shall have learned [illegible] will finish his sheet in a clear and artistic manner, and letter it [illegible] equal to sketches and [illegible] effect [illegible] the appearance of an otherwise [illegible] when that is sometimes [illegible] useless or indifferent lettering. [illegible] the beginner, [illegible] not be [illegible] sufficiently good draughtsman [illegible] his sheets in a satisfacto

Office Work. [illegible] [illegible] [illegible] [illegible]
[illegible] of [illegible] [illegible]
by [illegible] in pencil drawing [illegible]
[illegible] — The location of the [illegible]
upon the sheet should be [illegible] as [illegible]
to cover [illegible] any details [illegible]
portion of the survey. [illegible] [illegible]
should be put in neatly and [illegible]
and in case of [illegible] [illegible] [illegible]
ing to be [illegible] -urne finished — [illegible]
should finally follow [illegible]
noted as may be necessary. [illegible]
any accidents of the sheet [illegible]
The title and lettering should [illegible]
far as practicable, be in place.

16.

ffice Work.

fice Work.

[illegible] lege, the English [illegible] as [illegible] ped in a strict adherence to the [illegible] of the [illegible] ment.

The minutes of the [illegible] of latitude and meridians of longitude should be marked in figures at [illegible] where each right hand [illegible] the degree on the [illegible] and centre meridian [illegible]. —

Where the [illegible] are deter-mined by the topographer [illegible] names, colored [illegible] or [illegible] having the [illegible]

18.

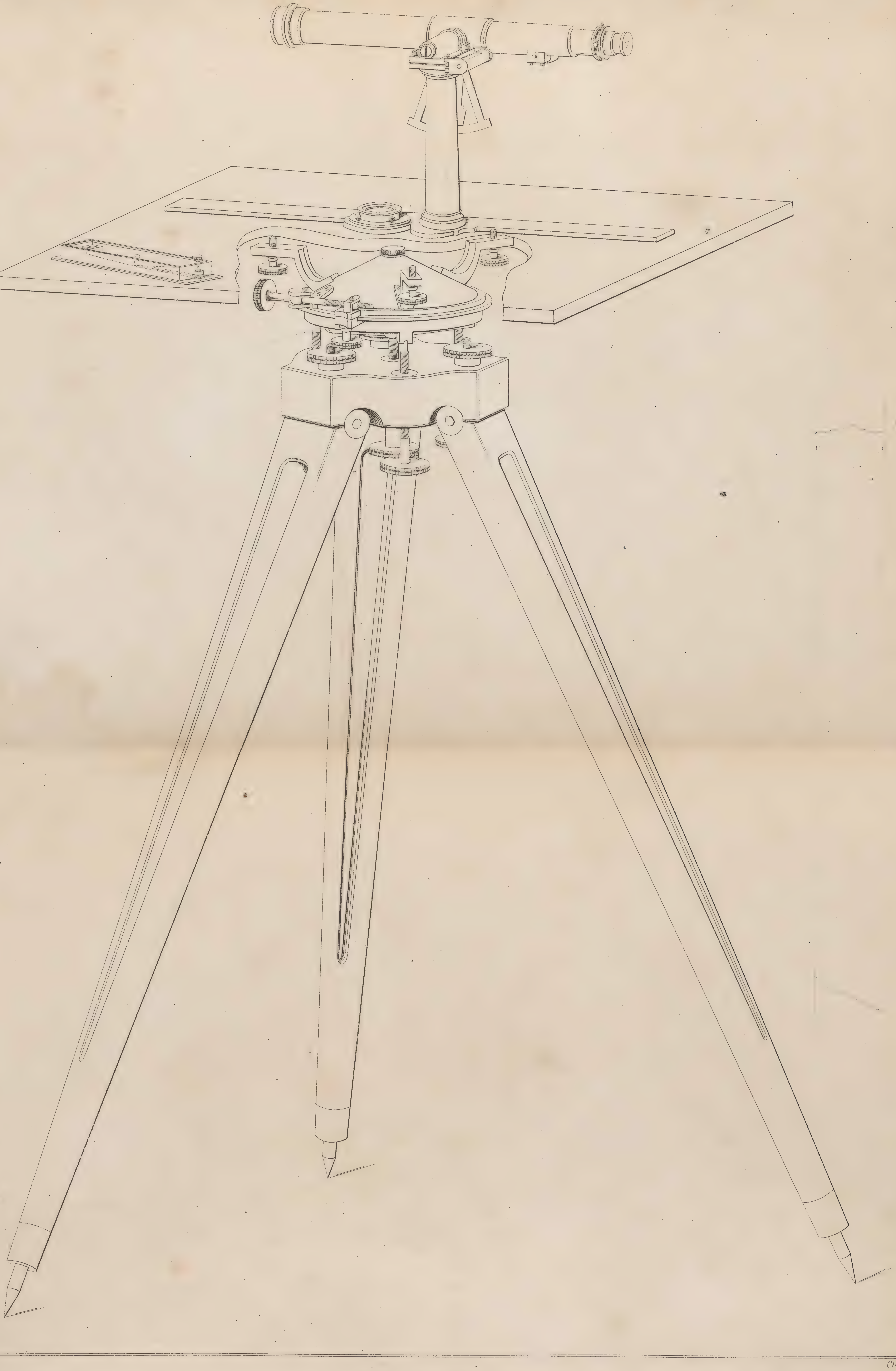
fice Work. be lettered upon the map.

The triangulation points should also be lettered, first being surrounded by a small circle.– The magnetic meridian should be drawn with a half fleur-de-lys at its head, and the true meridian, where no projection is used, with a full one.

The sheet is now finished and the labors of the topographer closed.–

16.

Diagrams Etc.



Chas. G. Krebs, Lith

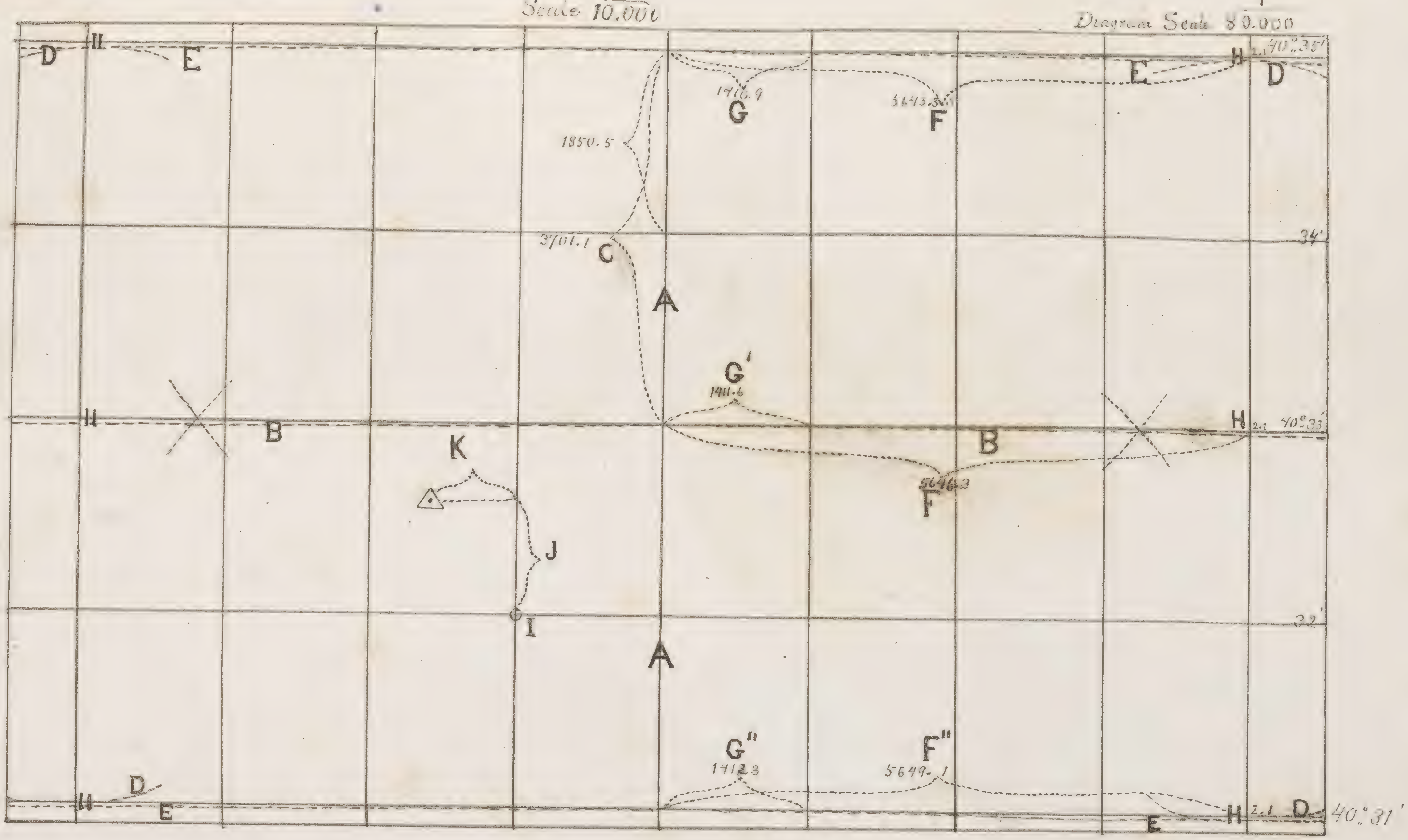
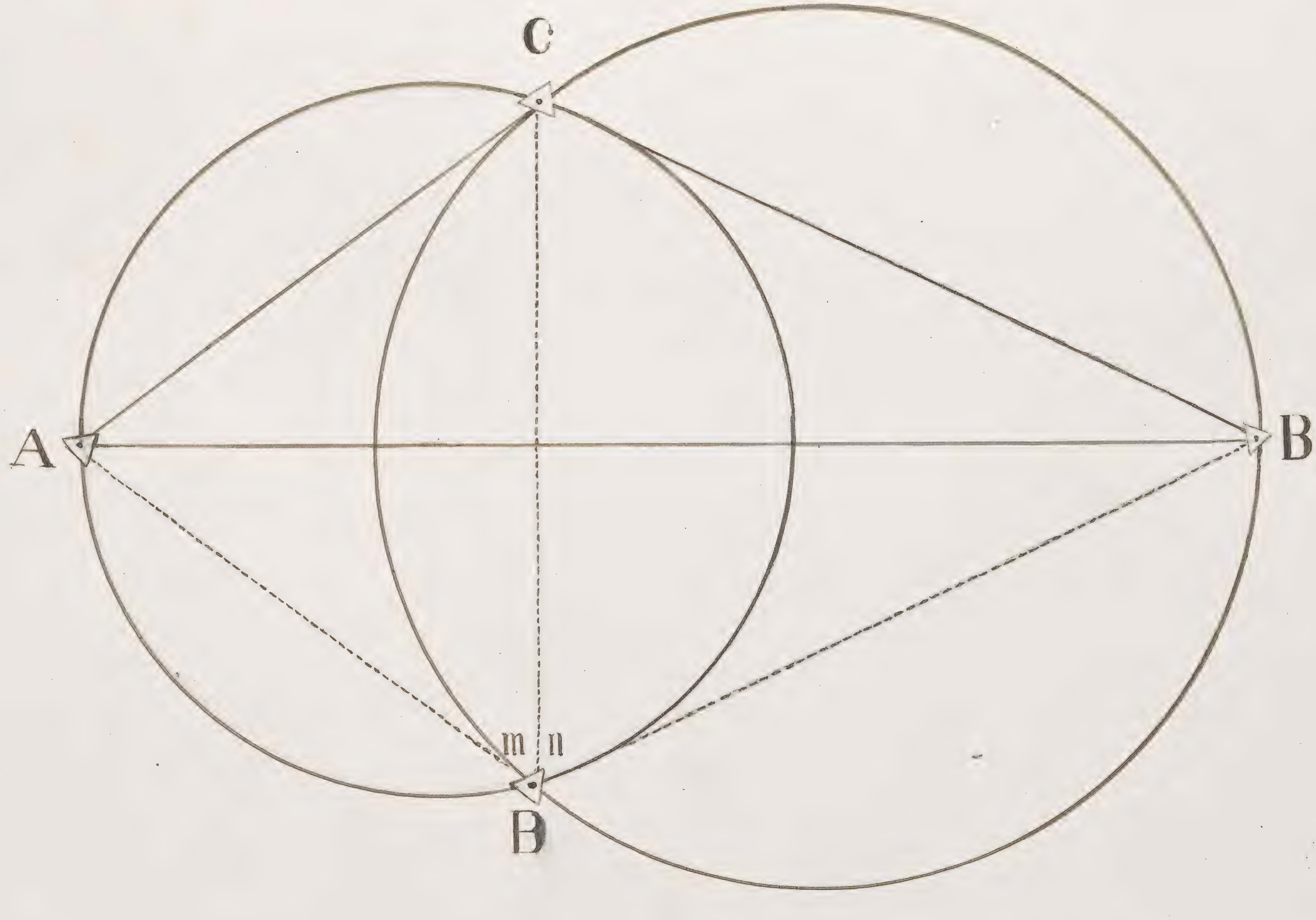

Scale 1/10.000
Diagram Scale 1/80.000
D
H
E
1416.9
G
5645.3
F
E
H
2.1
40°35'
D
1850.5
3701.1
C
34'
A
G'
1411.6
H
B
H
2.1
40°35'
B
K
5646.3
F'
J
I
32'
A
G''
1412.3
F''
5649.1
D
H
E
E
H
2.1
D
40°31'

DIAGRAM NO 1.

Illustrating mode of construction of Projection for Field Work. U.S. Coast Survey.



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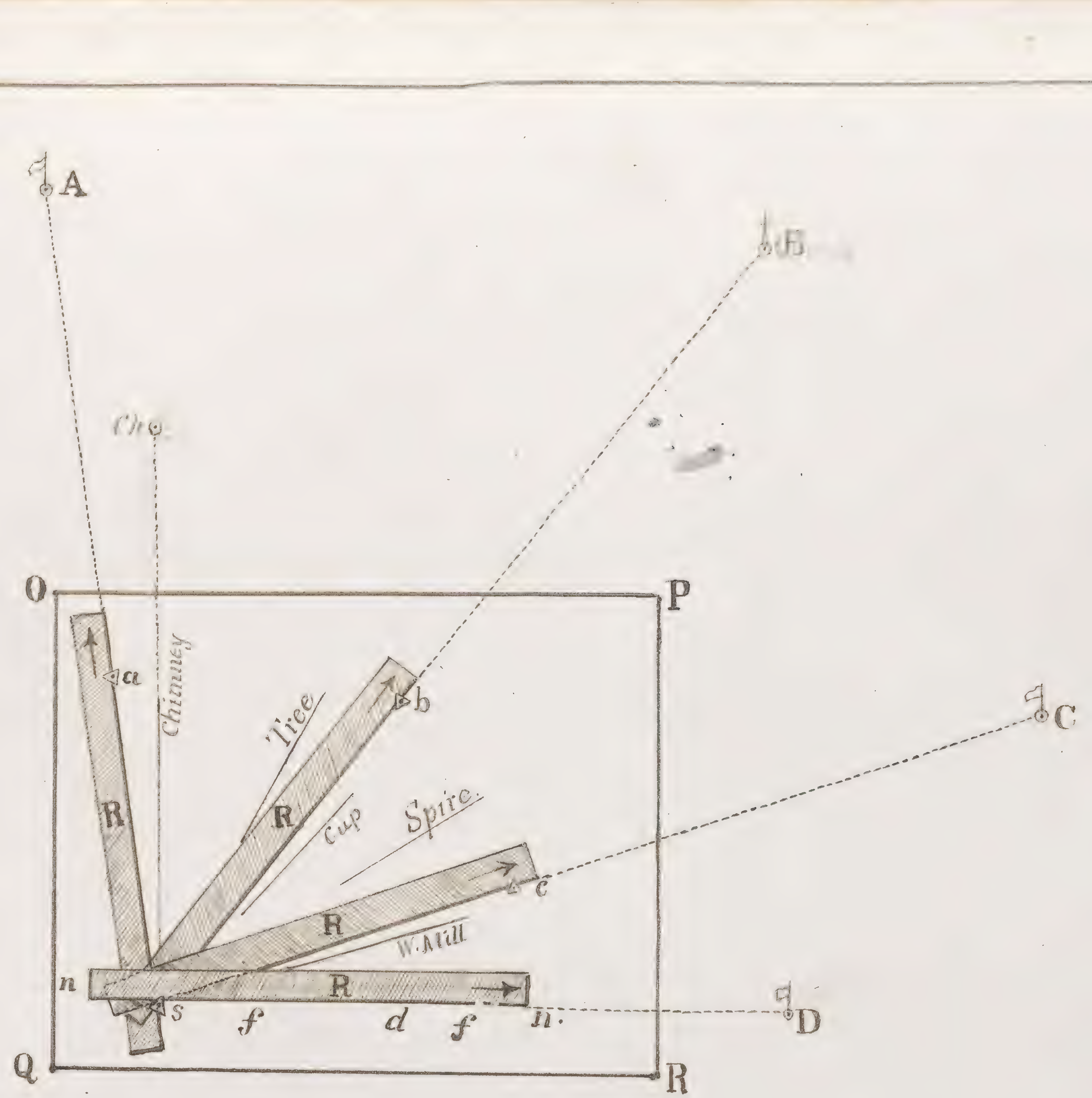

A
B
Ch
Chimney
O
P
a
Tree
b
C
R
R
Cup
Spire
c
R
W. Mill
n
R
s
f
d
f
n.
D
Q
R

DIAGRAM NO 3.

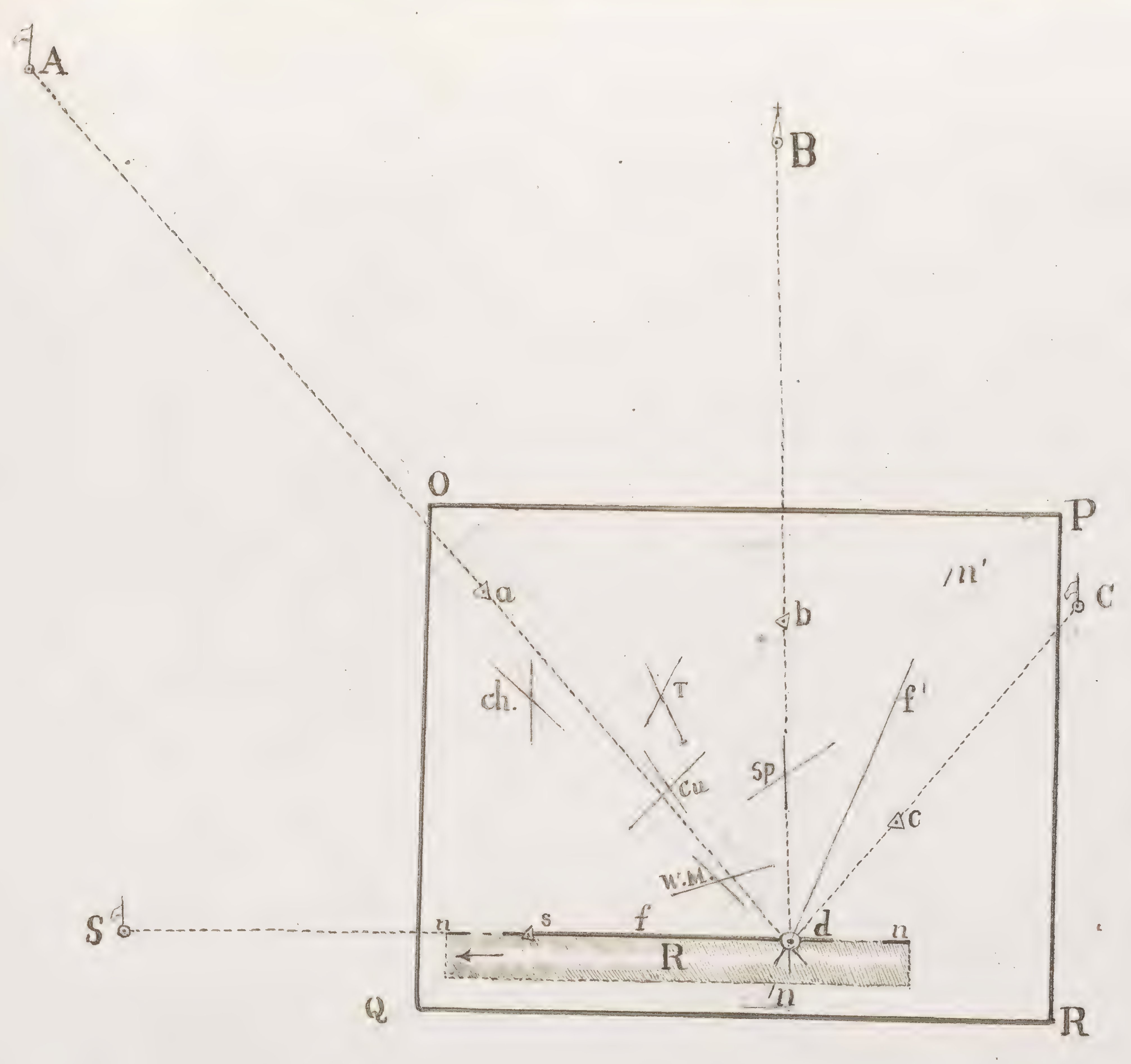

A
B
O
P
n'
C
a
b
ch.
T
f'
Sp
Cu
c
W.M.
S
n
s
f
d
n
R
Q
n
R

DIAGRAM NO 14.

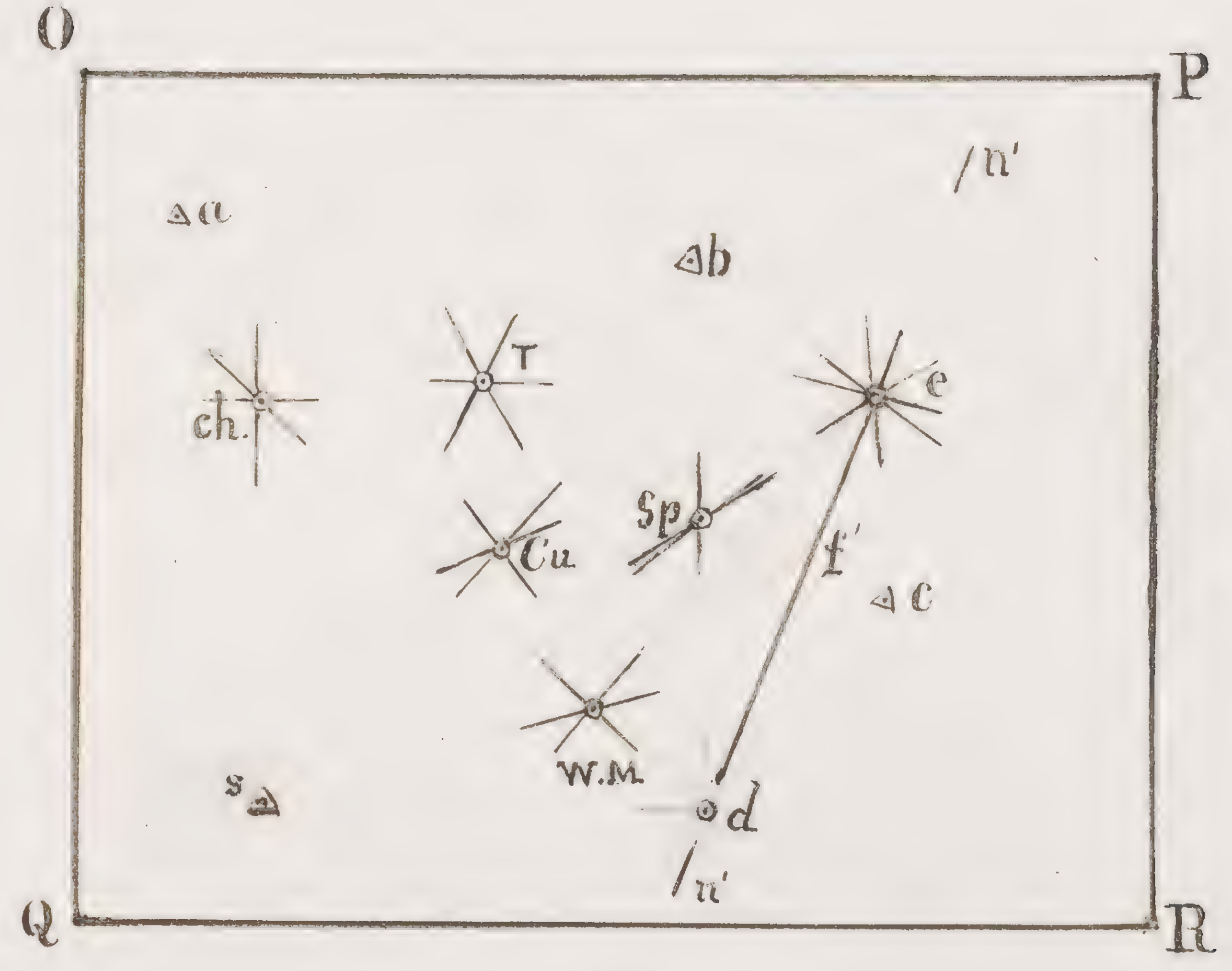

O
P
Q
R
a
b
c
n'
ch.
T
e
Sp
Cu
f'
W.M.
s
d
n'

DIAGRAM NO 1.

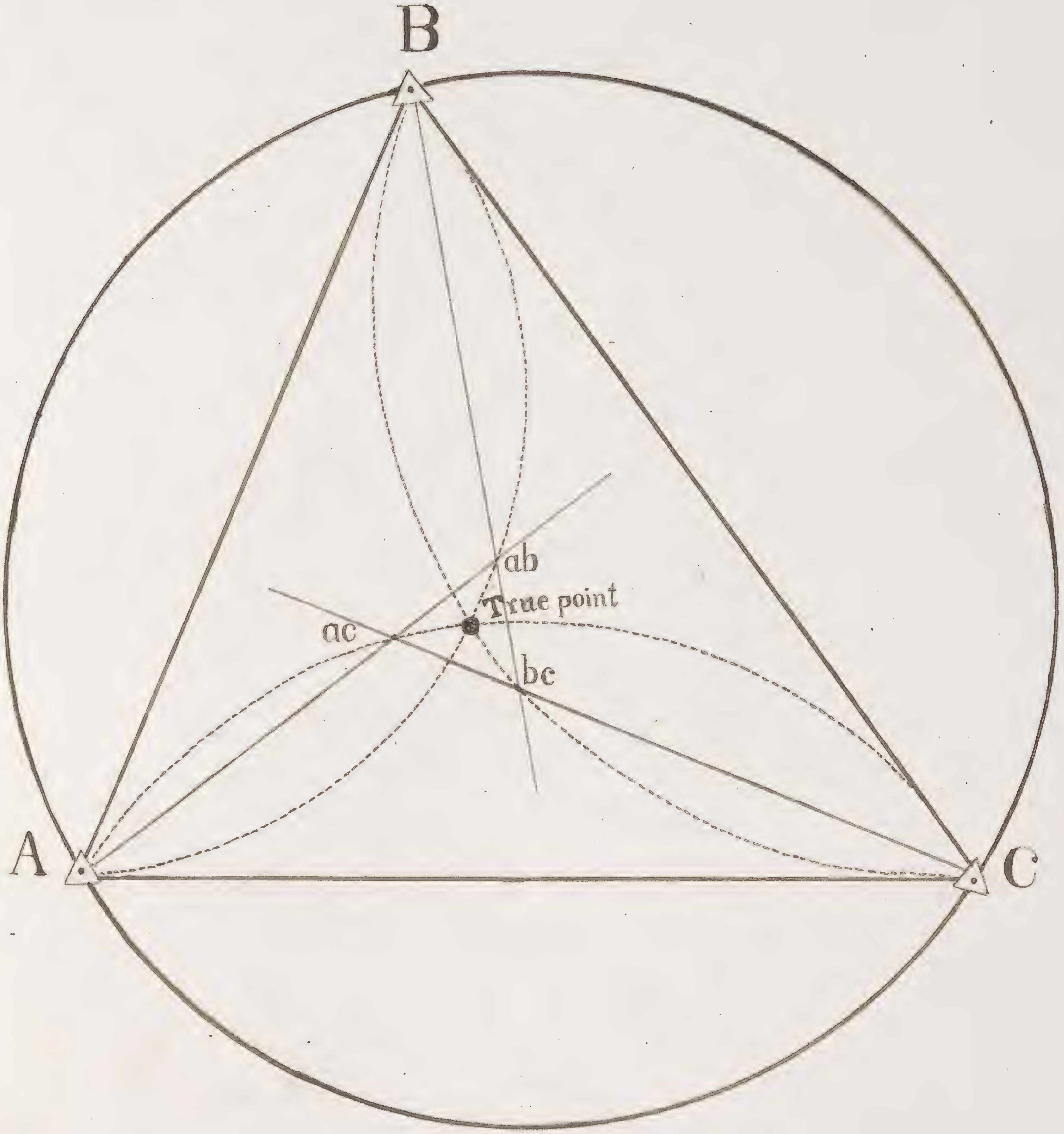

B
ab
True point
ac
bc
A
C

DIAGRAM NO 6.

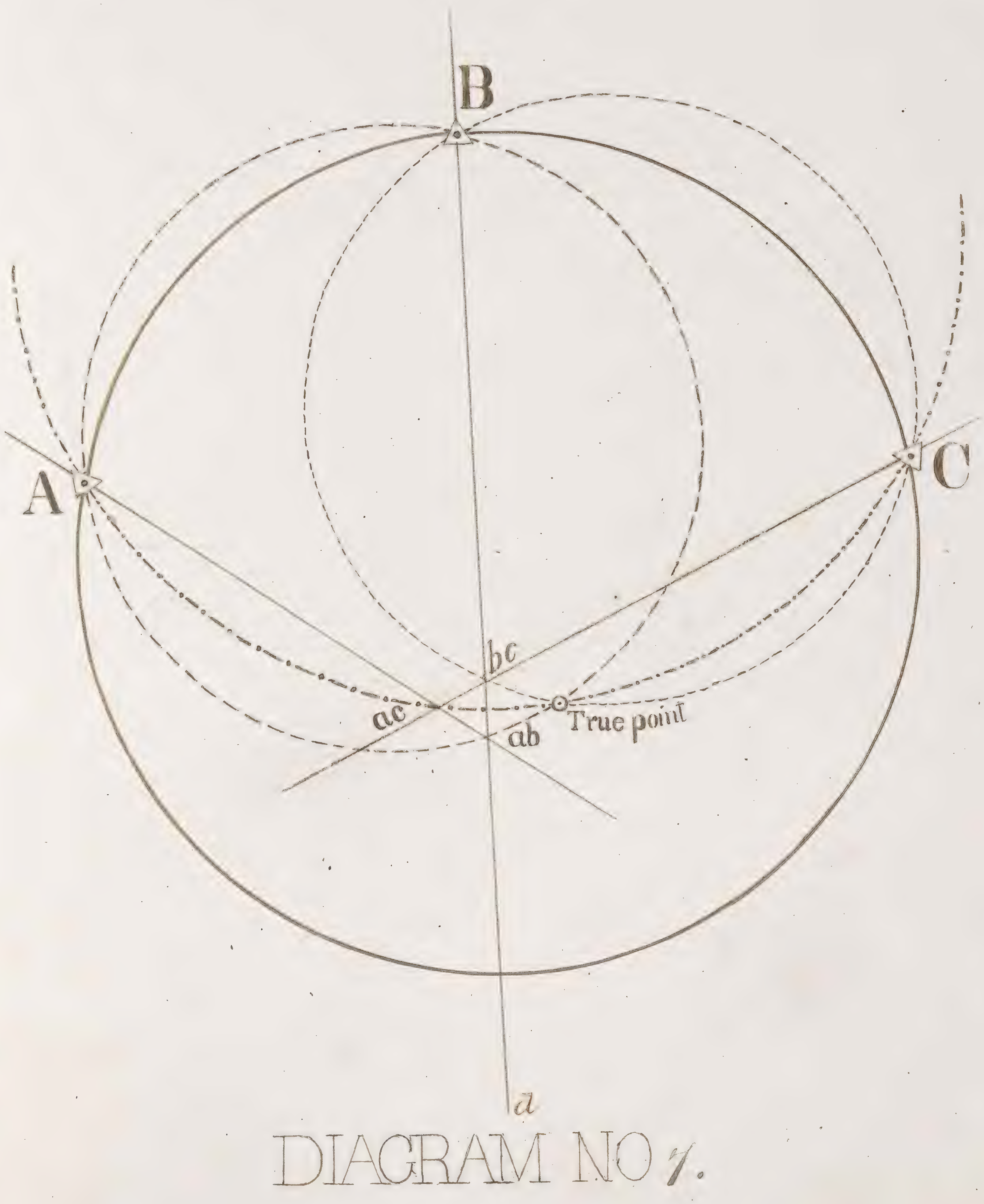

B
A
C
bc
ac
ab
True point
a

DIAGRAM NO 7.

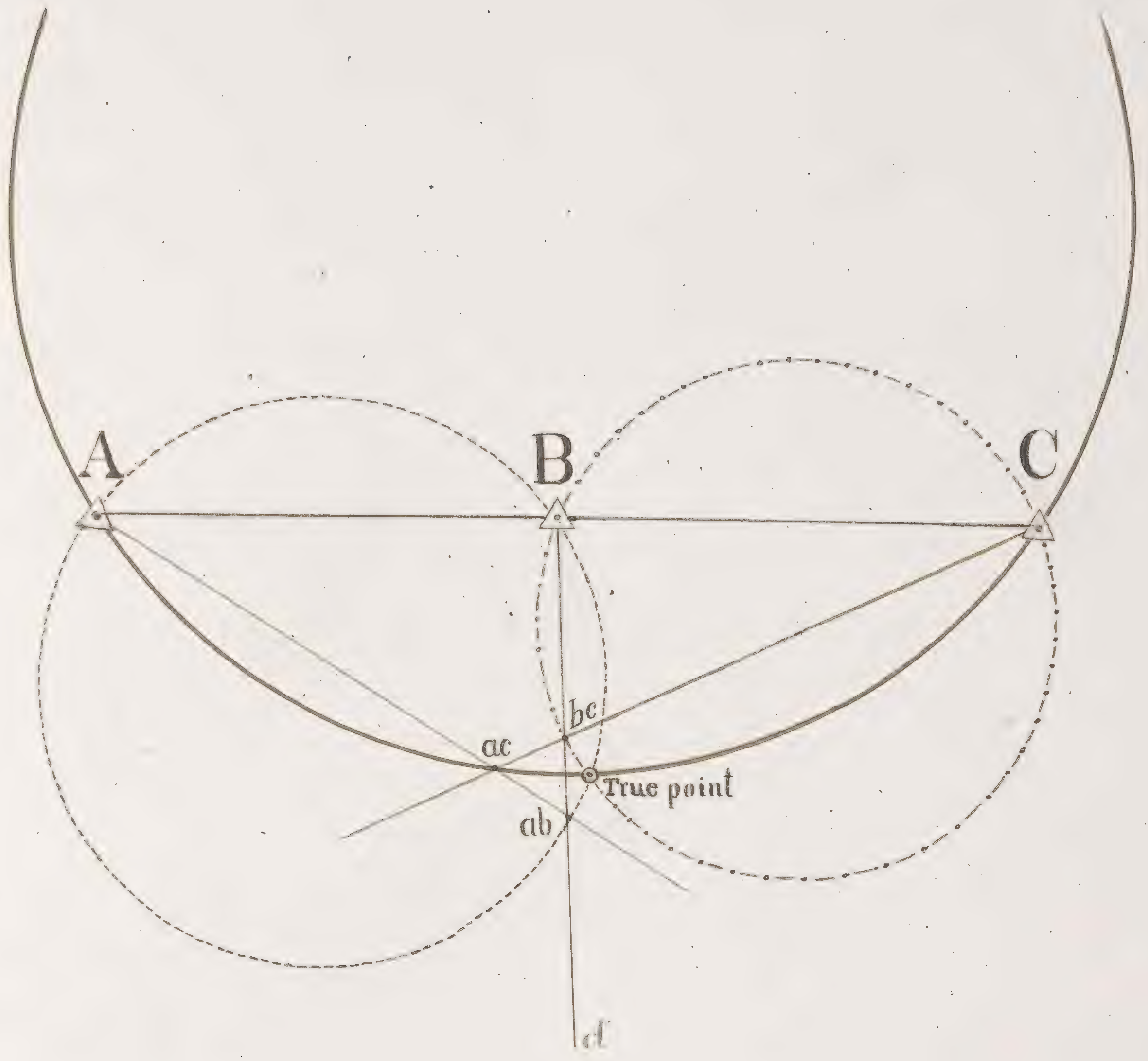

A
B
C
bc
ac
True point
ab
d

DIAGRAM NO 8.

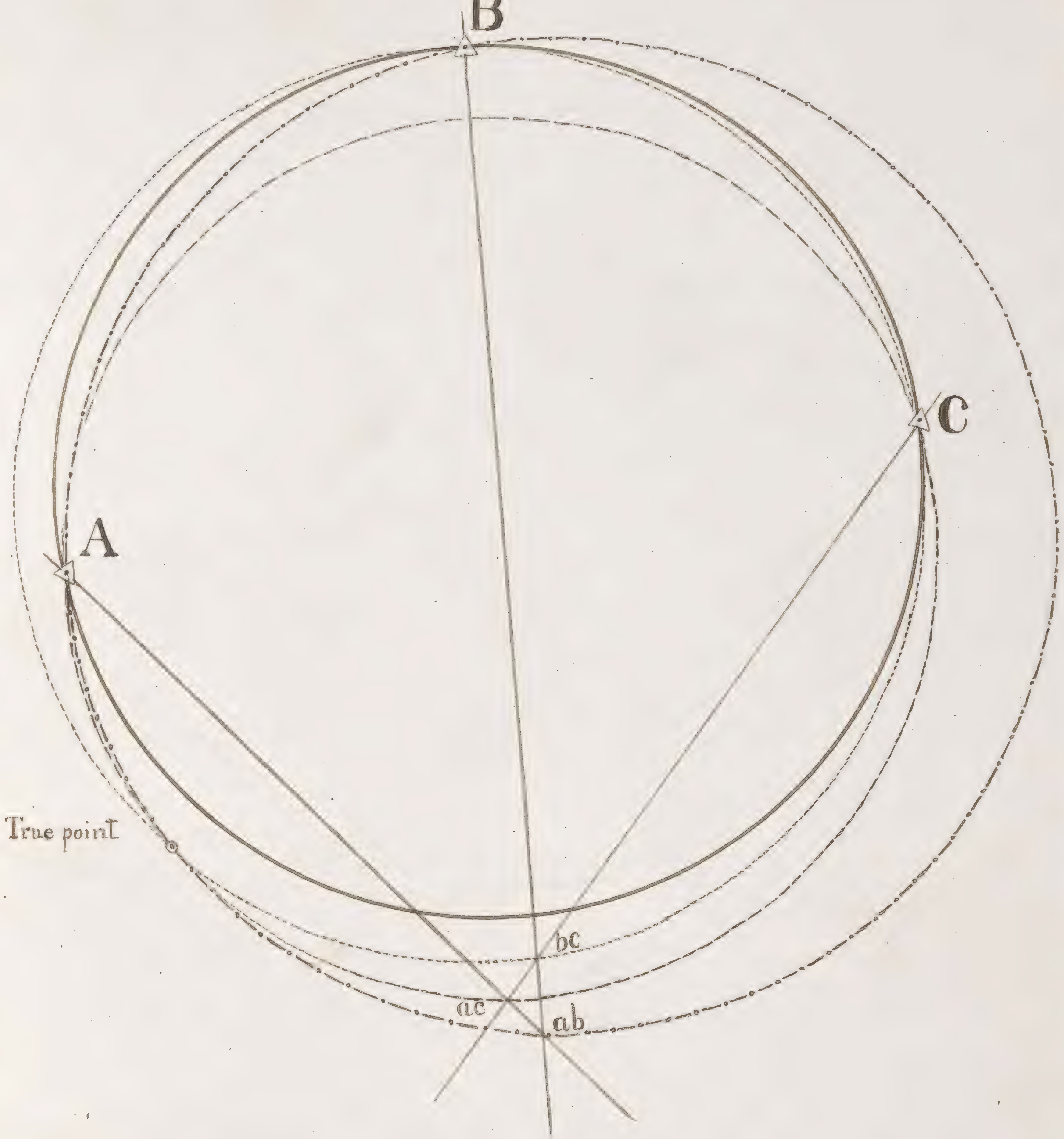

B
C
A
True point
bc
ac
ab

DIAGRAM NO 9.

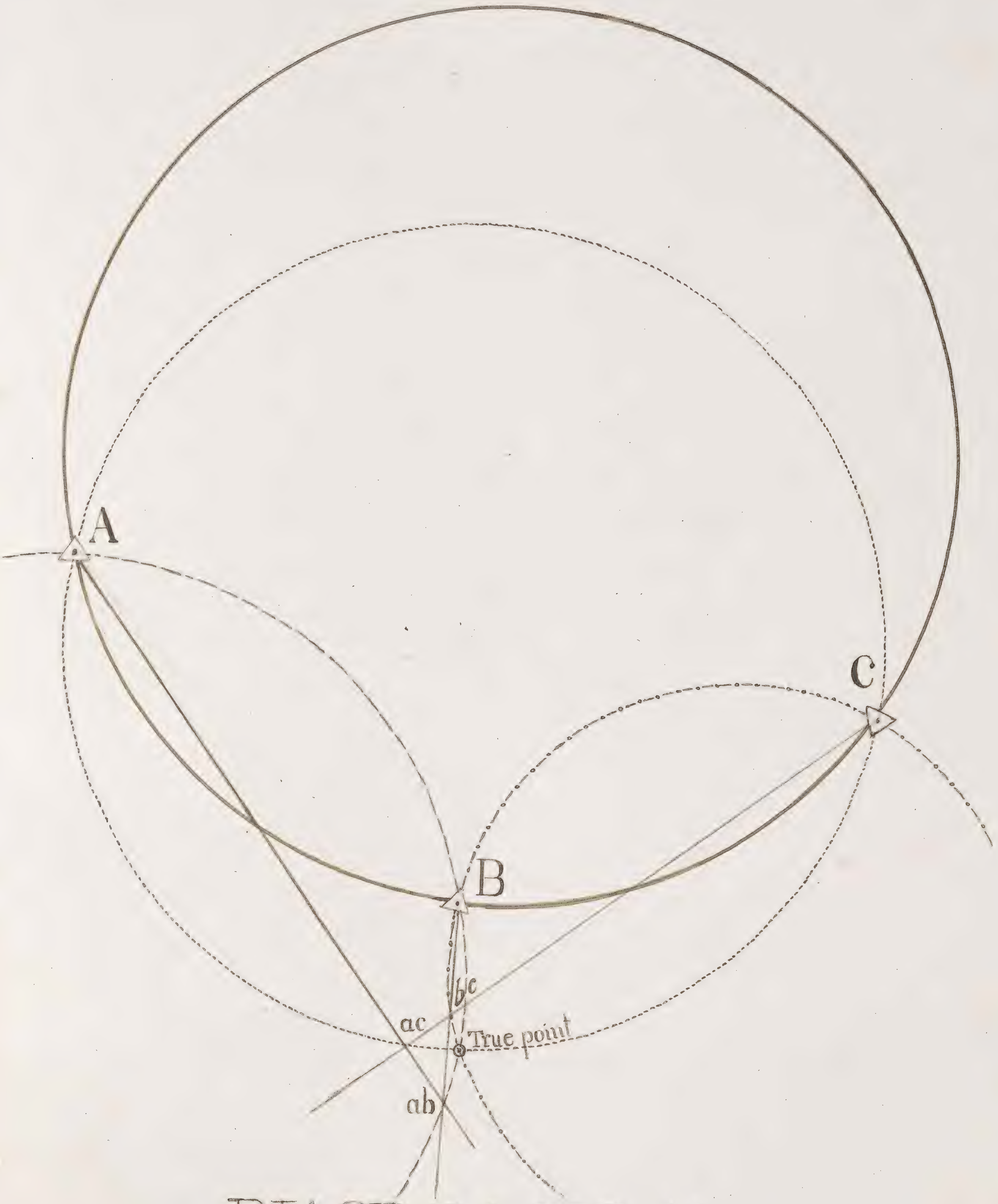

A
C
B
bc
ac
True point
ab

DIAGRAM NO 16.

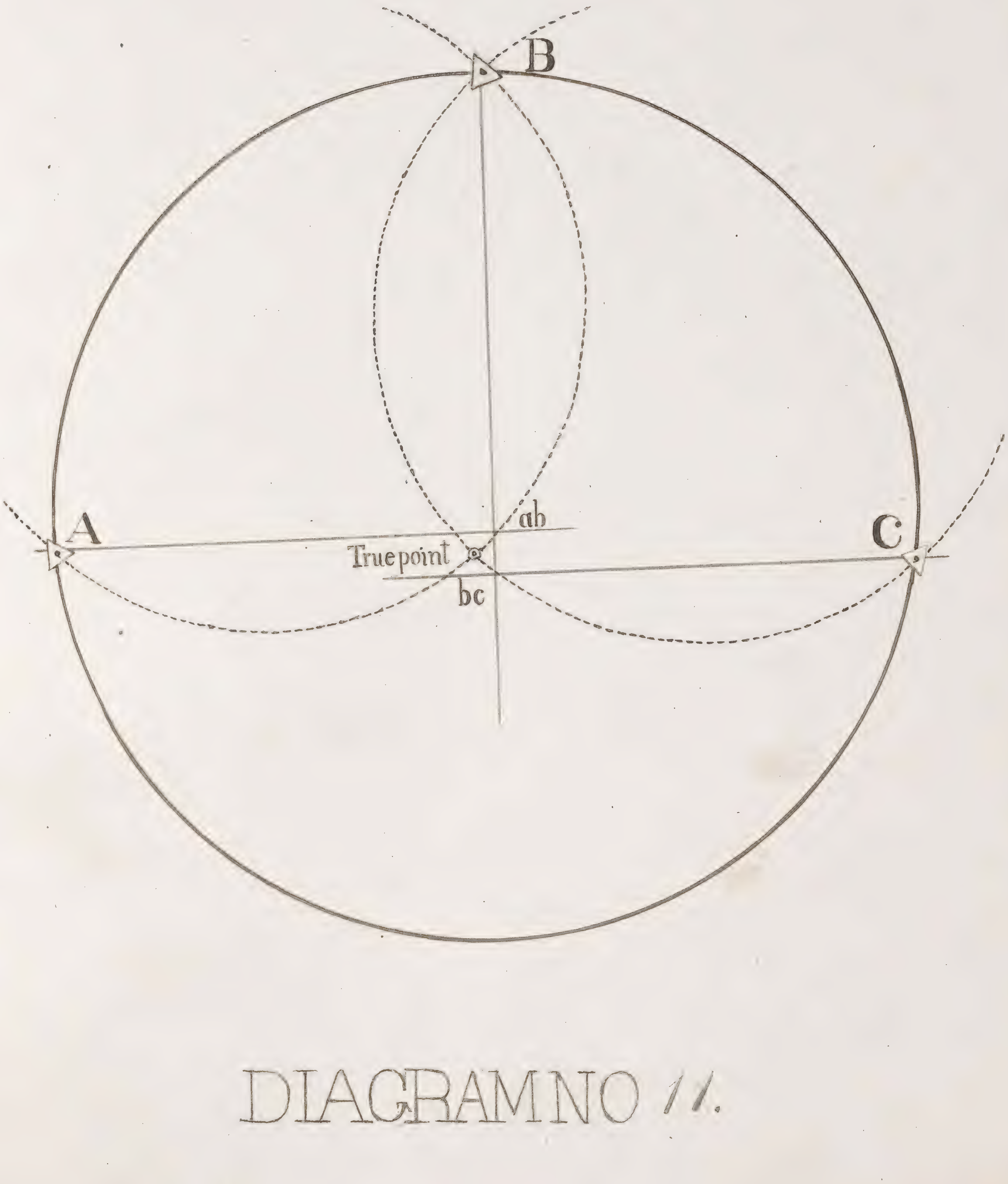

B
ab
A
True point
C
bc

DIAGRAM NO 11.

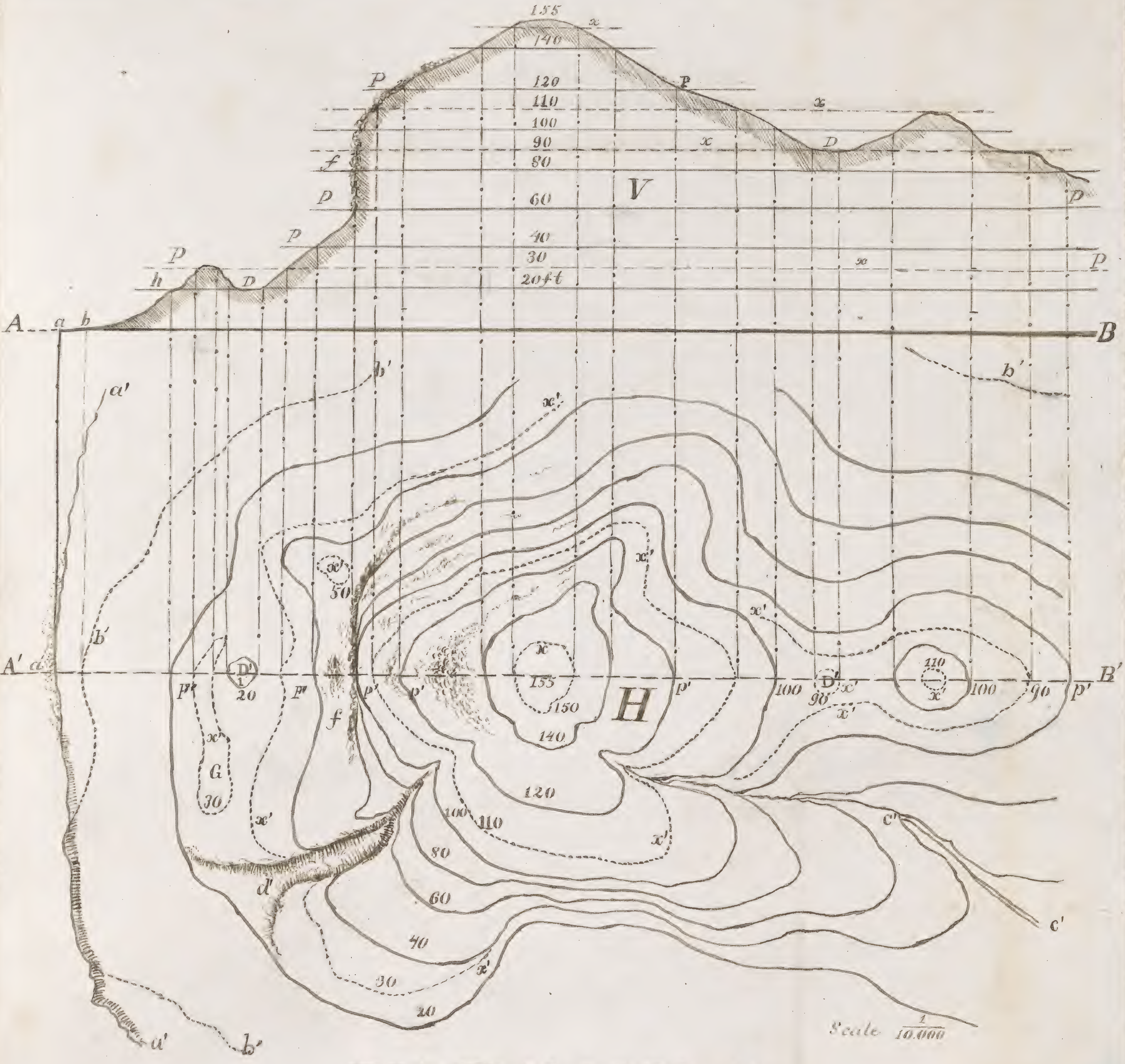
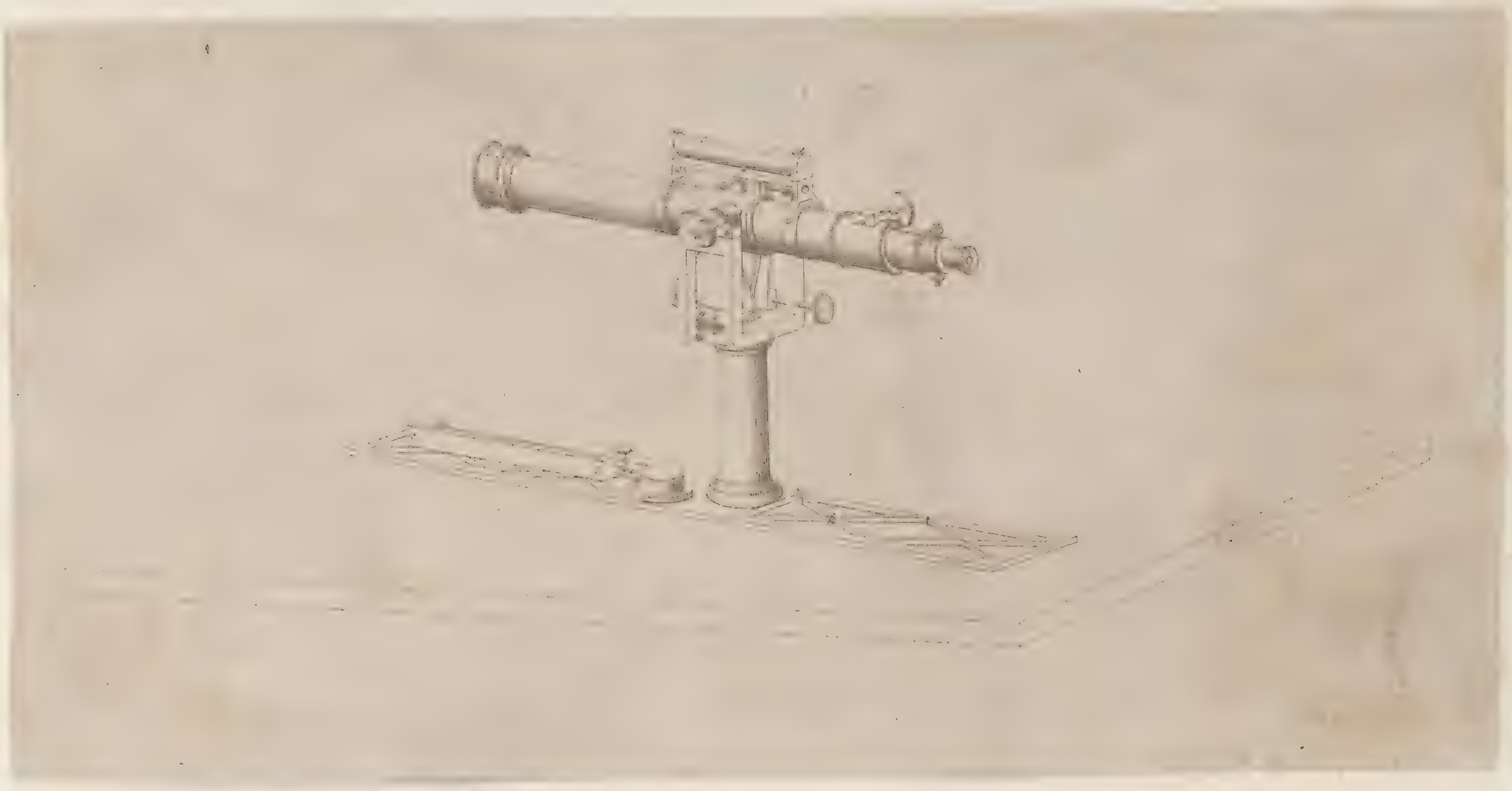
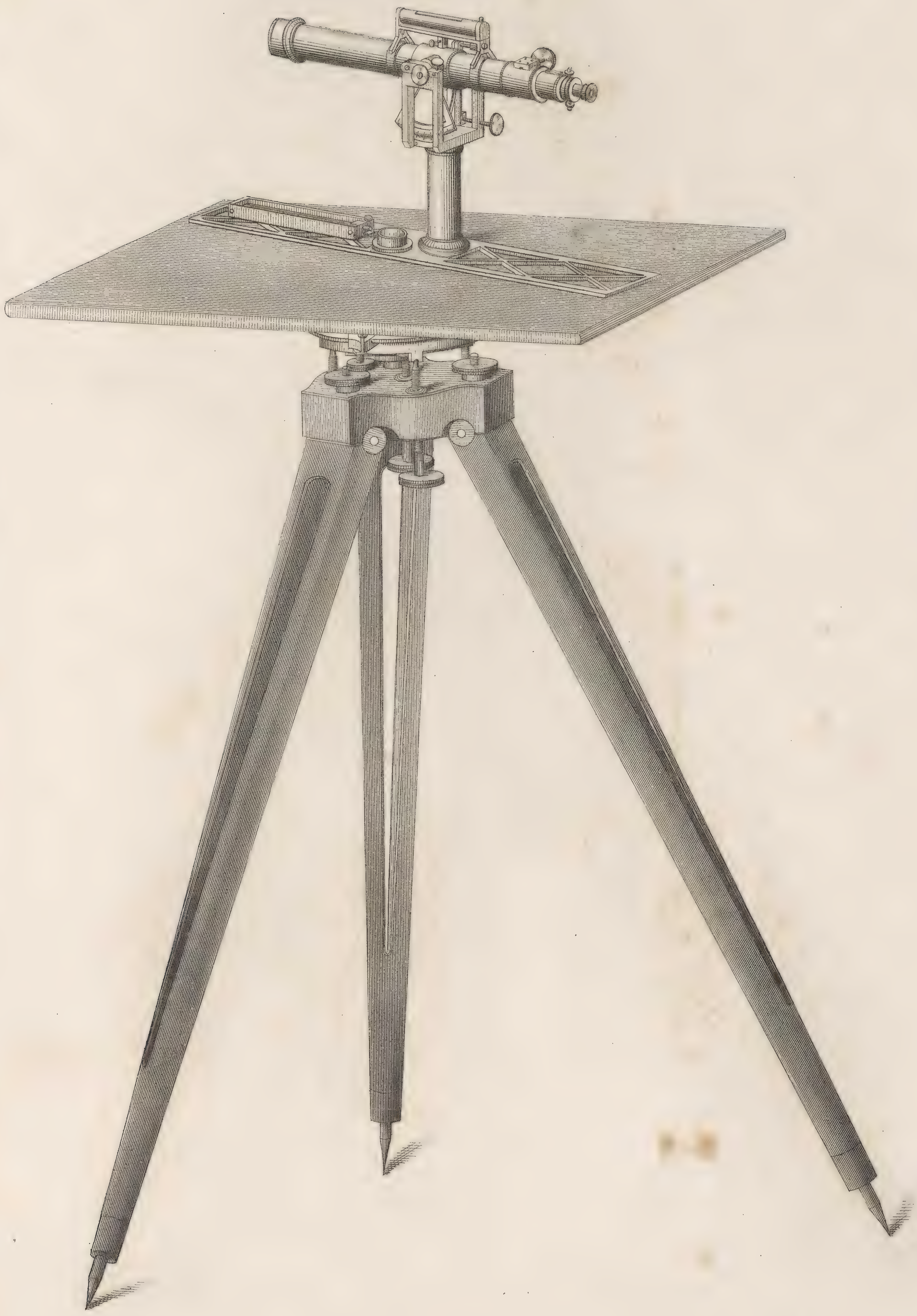

155
x
140
120
110
100
90
80
60
40
30
20 ft
P
f
D
V
h
A
a
b
B
a'
b'
x'
A'
D'
20
P'
f
p'
x
155
150
140
H
100
90
110
x'
G
30
120
110
100
80
60
40
30
20
d'
c'
B'
Scale 1/10.000

DIAGRAM NO 12.





A TREATISE ON THE PLANE TABLE, AND ITS USE IN TOPOGRAPHICAL SURVEYING,

BY

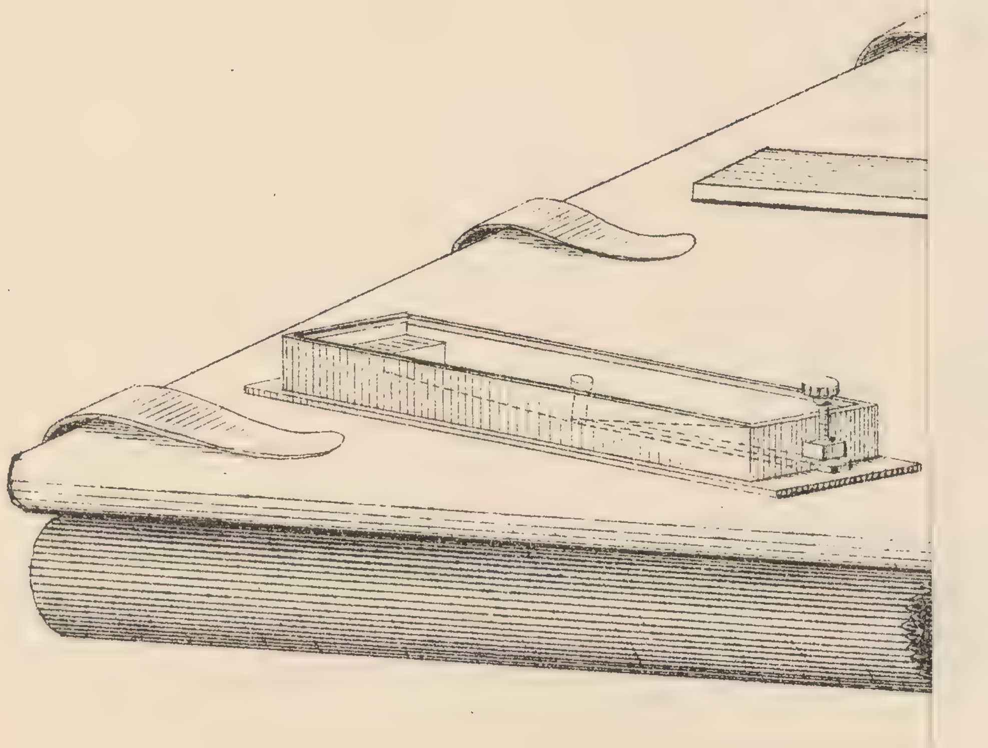
A. M. HARRISON, A. M.

ASSISTANT U. S. COAST SURVEY.

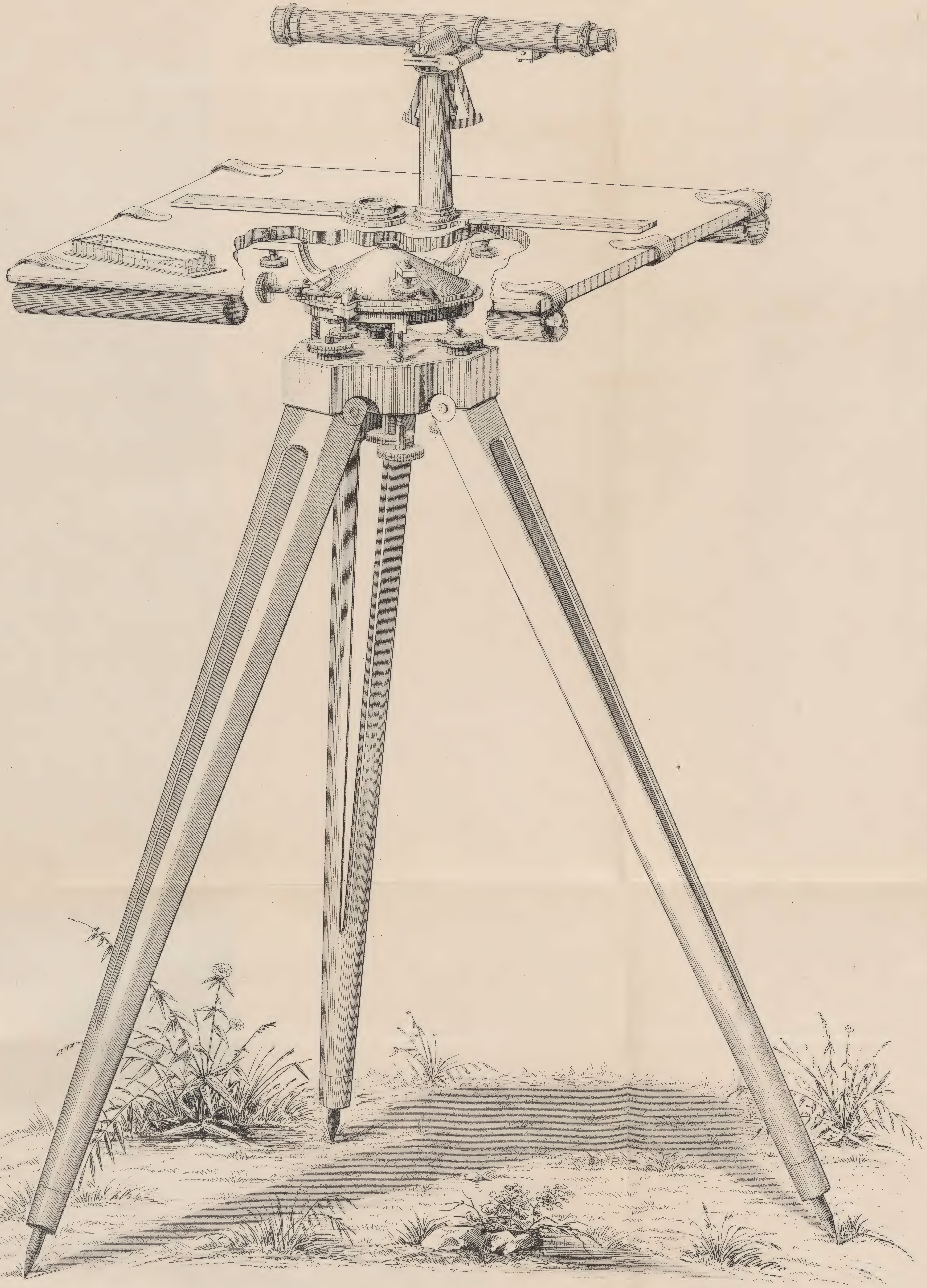
Abridged from the Original MSS.

1867.

No. 30.



PLANE TABLE.



Chas. G. Krebs, Lith.

ON THE PLANE-TABLE AND ITS USE IN TOPOGRAPHICAL SURVEYING.

The following description of the plane-table, in the shape in which it is at present employed upon the Coast Survey, and notes upon its use, are given as the results of a long experience of its good qualities on that work. Being the best instrument adapted for topographical purposes, it is desired to supply a want left by the very inadequate notices given of it in most American and English works, and to furnish topographical surveyors with a practical manual of its use. It may seem in some cases somewhat amplified, but those more familiar with it will overlook details intended for the benefit of beginners.

The invention of the plane-table is ascribed to Prætorius in 1537, but the first published description appears to be that of Leonhard Zubler, in 1625, who ascribes the "beginning" of the instrument to one Eberhart, a stonemason. From this time forward it has received successive improvements, chiefly from the Germans and French, until it has reached its present form, which seems to be in keeping with the existing state of science.

Description.—Topography is a more or less detailed representation, in the form of a map, of a certain area of ground, on a specified scale or proportion of nature, mechanically constructed by the measurement of angles, direct linear measurement, and tangential lines. In plane-table practice these are drawn in pencil upon the paper which is spread upon the table, and the details are filled in according to established conventional signs. The work is so conducted that the required figure is obtained in the field at once by the simultaneous measurement and plotting of the angles; and while it is done with as much accuracy as it could be plotted with a protractor, errors of transfer are avoided and much time saved.

The plane-table at present in use by the Coast Survey (see Sketch No. 30) is composed of a well-seasoned drawing board about thirty inches in length, twenty-four in width, and three-quarters of an inch thick, with bevelled or rounded edges. It is commonly made of several pieces of white pine, tongued and grooved together, with the grain running in different directions to prevent warping. It is supported upon three strong brass arms, to which it is attached by screws passing through them and entering the under side of the board, the three holes for the reception of the screws being guarded by brass bushings, and situated equidistant from each other and from the centre of the table. By means of these screws the board can be removed at will. The arms rest upon the sloping upper face of a rather flat hollow cone of brass, to which they are permanently fixed. Upon its lower edge or periphery this cone is fashioned into a horizontally projecting rim, the inferior face of which is as nearly as possible a perfect plane, and this in its turn rests upon a corresponding rim of a somewhat greater diameter projecting slightly beyond it. This second rim forms the upper and outer flange of a circular metal disk in the form of a very shallow cylinder. The inferior face or plane of the upper flange or rim has, at its contact with the superior face of the lower, a horizontal rotatory movement about a common centre, which is the centre also of the instrument, and the two are held together by means of a solid conical axis of brass extending upwards from the centre of the inner face of the lower disk. A socket of similar shape fits exactly over this axis, projecting downward from the inner side of the apex of the conical or upper disk. The two plates are held together by means of a mill-headed screw capping the cone from the outside, and which can be loosened or removed at pleasure.

A tangent screw and clamp fastened to the edge of the upper rim permit, when loose, the revolution of the table about its centre, and, when clamped to the lower limb, hold the table firm while the tangent screw gives a more delicate movement.

Three equidistant vertical projections of brass grooved on the under side, and cast in one piece with the under face of the lower disk, extending from the periphery towards the centre, rest upon the points of three large screws which come through a heavy wooden block below. This block, which is the top of the stand and is approximate in form to an equilateral triangle, is made of three pieces or horizontal layers, and is two and a quarter inches thick and very strong.

The three screws last mentioned have large milled heads, are quite stout, and play through the block from below by means of brass female screws let into it. They are the levelling screws of the instrument and are equidistant from its centre.

Upon the under side and centre of the lower metal disk is a socket containing a ball with a brass arm, which projects through the centre of the block from beneath. The lower end of the arm is threaded, and upon it plays a female screw with a large milled head, which can be relaxed or tightened at pleasure. This screw clamps the whole upper part of the instrument to the stand; it is loosened only before levelling, and kept securely clamped at all other times.

The block is supported upon three legs, and with them forms the tripod or stand of the instrument, the legs being of such a length as to bring the table to a convenient height for working, and so arranged as to be taken off at will, or closed so that their iron-shod and pointed ends can be brought together or moved outward, as may be required. For lightness the legs are generally made open through the middle of their length, though sometimes they are solid, and each one is fashioned at the top into a cylindrical form with an outer flange, the cylinder fitting into a groove on the under side and near the edge of a truncated vertex of the block. The flange, by coming in contact with the lower edge of the block, prevents a too great spread of the legs. A brass screw, which is connected at right angles with the middle of a movable bolt running through the axis of the cylindrical head of the leg and projecting through a hole in the block, is fastened above by a female screw with a large milled head.

A pair of compass sights or a watch telescope has sometimes been attached to the under side of the board of the plane-table. When the table has been put "in position," the watch telescope is directed to some well-defined object, and by after reference to it any movement which may have taken place out of position in the table during its use can be detected and adjusted. This, however, is but a complication of the instrument, and the same purpose can be more readily served by the alidade itself. The watch telescope has not been used in Coast Survey work.

Rollers have been attached to the under side of the table, taking the place of clamps for holding the map in its place; but these are very liable to get out of order, and are not regarded with favor by the best topographers.

The alidade consists of a brass rule about twenty-two inches long, having a circular level on its upper face. Near the middle of the rule is a perpendicular cylindrical column of brass called the "standard," surmounted by two square brass plates joined by screws, and supporting horizontally a conical journal, through which extends a closely fitting cone of brass, coming from and attached to the side of the telescope. This cone forms the axis of the vertical movement of the telescope, and is secured at the extremity by a screw which holds it in its place. The telescope itself has the usual cross-hairs and means of focal adjustment.

A transverse level is fastened to the edge of the upper of the two plates at the top of the standard by means of adjusting screws.

The telescope is so placed that its line of collimation is above and in the same vertical plane with the fiducial edge of the rule.

A vertical arc with a tangent screw and clamp is attached to the telescopic side of the lower brass plate, and, with a vernier which moves in arc as the telescope is raised or depressed, is used in the measurement of vertical angles for heights.

A small strip of brass is sometimes attached by means of horizontal hinges to the edge of the rule, after the manner of the ordinary parallel rule, for the purpose of obviating the necessity of watching the exact contact of the edge of the rule with the point while sighting; but, as it is liable to the same objection as that instrument, it has not come into general use.

A *declinatoire*, consisting of a rectangular metal box containing a needle so arranged that when pointing north it is parallel to the outer straight edge of the box; a scale of equal parts of brass or German silver; a set of metal clamps for fastening the map to the table; a pair of sharp dividers; India-rubber, pencils, and a pen-knife, complete the list of essentials for prosecuting plane-table work.

ADJUSTMENTS.—From the nature of the service in some sections of the country the plane-table is often necessarily subjected to rough usage, and there is a constant liability to a disturbance of the adjustments; still, in careful hands, a well-made instrument may be used under very unfavorable conditions for a long time without being perceptibly affected. One should not fail, however, to make occasional examinations, and while at work, if any difficulty be encountered which cannot otherwise be accounted for, it should lead directly to a scrutiny of the adjustments.

1. *The fiducial edge of the rule.*—This should be a true, straight edge. Place the rule upon a smooth surface and draw a line along the edge, marking also the lines at the ends of the rule. Reverse the rule, and place the opposite ends upon the marked points, and again draw the line. If the two lines coincide, no adjustment is necessary; if not, the edge must be made true.

There is one deviation from a straight line, which, by a rare possibility, the edge of the ruler might assume, and yet not be shown by the above test; it is when a part is convex, and a part similarly situated at the other end concave, in exactly the same degree and proportion. In this case, on reversal, a line drawn along the edge of the rule would be coincident with the other, though not a true right line; this can only be tested by an exact straight edge.

2. *The level attached to the rule.*—Place the instrument in the middle of the table and bring the bubble to the centre by means of the levelling screws of the table; draw lines along the edge and ends of the rule upon the board to show its exact position, then reverse 180°. If the bubble remain central, it is in adjustment; if not, correct it one-half by means of the levelling screws of the table, and the other half by the adjusting screws attached to the level. This should be repeated until the bubble keeps its central position, whichever way the rule may be placed upon the table. This presupposes the plane of the board to be true. If two levels are on the rule they are examined and adjusted in a like manner.

Great care should be exercised in manipulation, lest the table be disturbed.

3. *Parallax.*—Move the eye-glass until the cross-hairs are perfectly distinct, and then direct the telescope to some distant well-defined object. If the contact remain perfect when the position of the eye is changed in any way, there is no parallax; but if it does not, then the focus of the object-glass must be changed until there is no displacement of the contact. When this is the case, the cross-hairs are in the common focus of the object and eye glasses.

4. *To make the line of collimation perpendicular to the axis of revolution of the telescope, and the axis of revolution parallel to the plane of the rule.*—The instrument is set up and carefully levelled, and the cross-hairs directed to a plumb or other vertical line. If the cross-hairs cover the line when the telescope is elevated and depressed, the adjustments are perfect; should they deviate, however, from the vertical line, this error may be attributable to two causes: 1st, the line of collimation is not perpendicular to the horizontal axis; or, 2d, the axis is not horizontal, and consequently not parallel to the plane of the rule. In the first case the motion of the cross-hairs will be in a curve, and, upon being made to cover the vertical line when the telescope is horizontal, will deviate from it to the *same* side both upon elevation and depression. In the second case the movement of the cross-hairs will be in a straight line oblique to the horizon, and, when made to cover the vertical line when the telescope is horizontal, they will, upon being elevated and depressed, appear upon *different* sides of the vertical line. These two cases will be considered separately.

When the construction of the telescope admits of it, the perpendicularity of the line of collimation to the axis may be examined as follows: Direct the cross-hairs to a well-defined, distant object, as nearly upon a level with the telescope as may be, draw a line along the fiducial edge; then reverse the rule 180°, again placing the edge along this line, revolve the telescope upon its axis and again observe the object; if the cross-hairs cover it, the adjustment is perfect; if not, one-half the error must be corrected by moving the cross-hairs by means of the adjusting screws of the diaphragm, and the other half with the tangent screw of the table, and the operation should be repeated until the adjustment is complete.

In using the method just given it may be taken for granted that the line of collimation revolves in the vertical plane of the fiducial edge, as any error arising from this not being the case would be inappreciable.

After this adjustment the horizontality of the axis should be examined. Direct the cross-hairs to a distant, well defined, elevated or depressed object, having the table carefully levelled; draw a line along the fiducial edge, reverse the rule, and again direct towards the object; if the cross-hairs cover it the axis is horizontal; if they do not, one half of the deviation should be corrected by means of the screws attaching the upper plate to the top of the standard, or by means of the screws attaching the standard to the rule. The level attached to the axis should then be made central.

5. *To make the line of collimation parallel to the vertical plane of the fiducial edge.*—The exact parallelism of these is not absolutely necessary, but it is essential that the deviation should remain constant. This adjustment may be examined by means of two needles stuck in the table. The table is turned so that the needles sight exactly to some distant object; the fiducial edge is then placed against them and the telescope directed to the object. If the cross-hairs bisect it, the adjustment is correct; but if they do not, it can be corrected by means of the screws attaching the standard to the rule.

6. *Zero of the vertical arc.*—When the line of sight is horizontal, the vernier of the vertical arc should read 0°, or the index error should be known. This may be examined by means of the distant sea horizon, or by setting up the alidade so that the centre of the telescope is in the line of sight of an accurately adjusted levelling instrument, and then directing both instruments, while level, to a distant object; if any error be discovered, it may be corrected by setting the vernier at 0°, and adjusting the horizontal wire to the sea horizon or object.

When the above means are not available, the following method may be used: Set up the instrument at a point, measure the angle of elevation or depression of a distant object, remove the instrument to that object, and measure the angle of depression or elevation of the first point. These angles should be equal if the adjustment be correct; and if not equal, the index error will be one-half the difference of the two readings.

The following method of making this adjustment, where you have neither a separate level, a sea horizon, nor an elevation, may be employed: Set up the table and level it carefully on any level piece of ground between two equidistant points A and B, say 600 or 800 metres apart. Determine with the table the difference of level of these two points, and remove the table to A. Measure carefully the distance from the ground to the centre of the axis of the telescope, and add or subtract this from the difference of level of the point B, according as it is lower or higher than A. Set up a target or distinct point at this height at B, direct the cross-hairs upon it, and correct the vernier accordingly.

A longitudinal striding level placed upon the telescope, or a level permanently fastened upon the top of the telescope parallel to the optical axis, and adjusted to the horizontal wire, will give the error at once.

Plane-table.—With regard to the plane-table proper, a disturbance of its good working condition generally arises from accidents resulting from carelessness or from undue exposure of the board to the inclemency of the weather, and where these injuries are of a serious nature the mechanician only can apply the proper remedies. A coating of shellac has been suggested, whereby the shrinkage and warping of the board is said to be prevented "in a very marked degree;" but well-seasoned wood and fidelity in construction must be the main reliance of the surveyor.

PAPER.—In addition to faulty adjustment of his instrument the topographer has an additional source of error to guard against, arising from the expansion and contraction of the paper, due to its hygrometric nature. From the exposure to which a sheet is subject while in use in the field, and the occurrence of almost unceasing atmospheric changes, it can hardly ever be considered for any great length of time as fixed in its relative proportions; and the difficulty is greatly increased from the want of uniformity in this variation in the different parts of the sheet and in different directions.

When points are determined by intersection, the effect of contraction and expansion may be uniform enough to be comparatively unimportant; but in running long traverses without side checks the effect is always felt.

In plotting long-measured distances the most feasible method of correction is to measure a minute of latitude near the place of plotting; and as the lengths of all these minutes on the sheet is the same, a comparison with the scale can at once be made and the percentage of error determined. When the sheet has no projection, squares of 1,000 metres constructed upon it will answer the same purpose.

In case of trouble with the points arising from this cause, there is but one remedy, and that is by the system of compensation as treated of in the article on field-work.

SCALES.—The very simple and ingenious decimal system of scales for maps adopted by the French is that in use upon the coast survey. In this system the scale of any map is represented by a fraction, whose

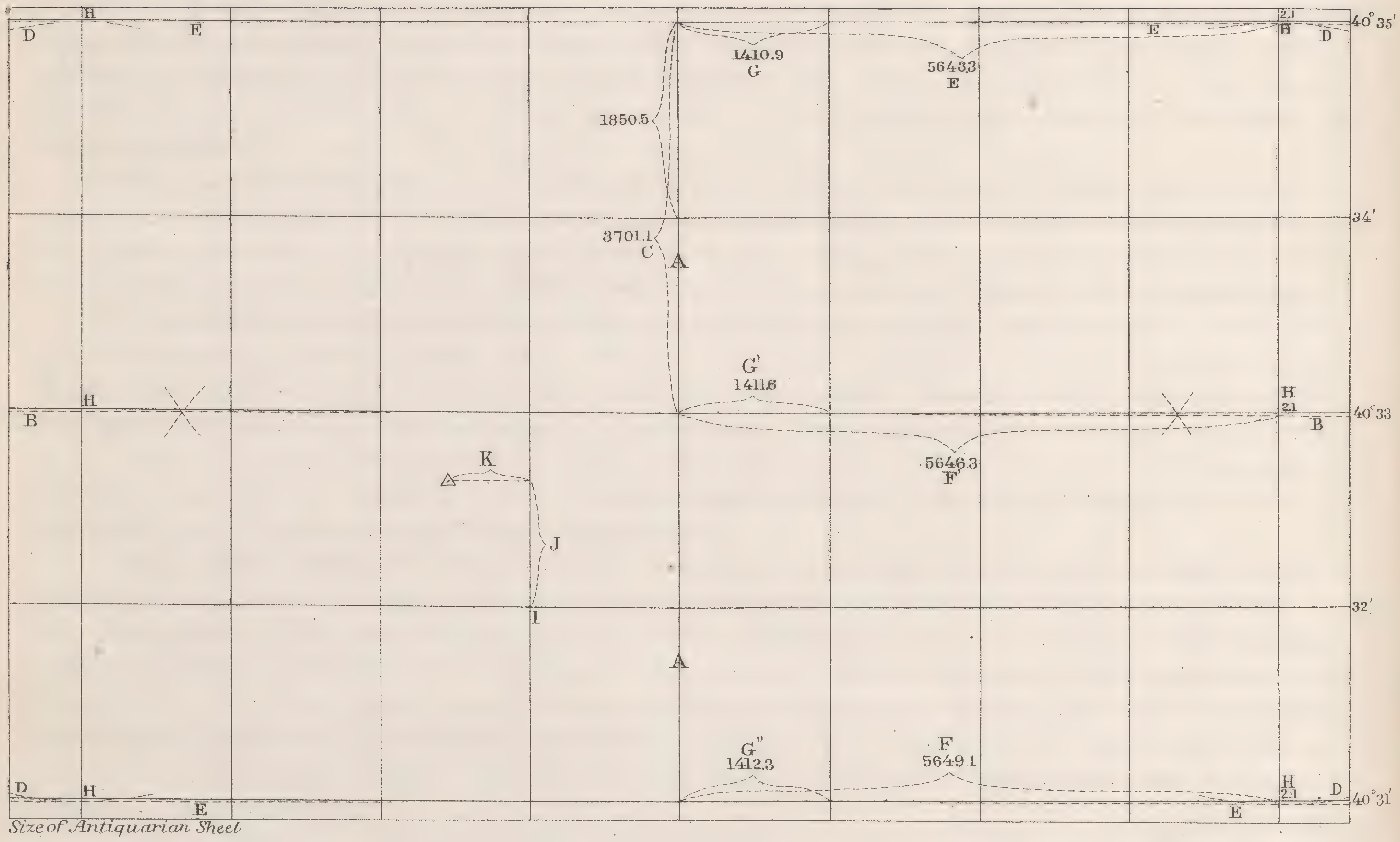

H
D
E
2.1
H
E
D
40° 35′
1410.9
G
5643.3
E
1850.5
34′
3701.1
C
A
G′
1411.6
H
B
H
2.1
B
40° 33
K
5646.3
F′
J
I
32′
A
G″
1412.3
F
5649.1
D
H
E
H
2.1
D
E
40° 31′
Size of Antiquarian Sheet

Diagram illustrating the mode of constructing the Conic Projection for Plane Table Work, Scale $\frac{1}{10,000}$
Scale of Diagram, $\frac{1}{80,000}$

numerator is unity and whose denominator is some multiple of two or five, as $\frac{1}{20000}$, $\frac{1}{10000}$, $\frac{1}{5000}$, $\frac{1}{2000}$, meaning that any distance on the map is one twenty-thousandth, one ten-thousandth, &c., of its actual dimensions on the ground. Thus, on a scale of $\frac{1}{10000}$, one decimetre on the map will represent an actual distance of 1,000 metres.

Any other desirable scale can, of course, be used, as a given number of inches to a mile; and in case of triangulating from a base, as in a reconnoissance, no scale even need be adopted. By assuming two points on the sheet as the extremities of the base, and working from them, a correct delineation of the country can be obtained before the base has been measured. After measurement the scale of the map can be ascertained by dividing the length of the base on the map by its length on the ground, both expressed in the same unit.

In those regions where there is much detail, $\frac{1}{10000}$ is the scale generally used for field-work, while in others, where there is but little minute work, $\frac{1}{20000}$ is employed. Less than the latter is never used for field sheets. In some cases, such as surveys of cities, wharves, &c., $\frac{1}{5000}$ may be used; and in certain rare instances, as in surveys for the location of batteries, the mapping of forts and other works, and sites for light-houses, still larger scales are sometimes found necessary.

The diagonal scales of equal parts used on the coast survey with the plane-table, for the purpose of plotting measured distances, correspond with the scales of the maps. They are of metal, and sufficiently hard to stand long wear from the points of the dividers.

PROJECTIONS FOR FIELD-WORK.—The conical projection is that used in the coast survey for field-work.

The orienting of the sheet is determined by various considerations. It should include as many triangulation points as possible; it should duly conform to the position of sheets already surveyed in the same neighborhood; and it should embrace the area of the proposed survey in the manner most convenient for work, and most effective for the artistic appearance of the sheet when finished.

A sketch giving the triangulation points and the approximate shore line being before the draughtsman, he proceeds as follows:

The limits of the sheet having been determined, the middle meridian A (see appended sketch) is located and drawn, and its intersection with the most central parallel determined, at which point the perpendicular B is erected.

The number of minutes of latitude on the central meridian, above and below the central parallel, being known, take the corresponding distance from Table VI, "Projection Tables," C. S. Report, 1853, Appendix No. 39, from under the head "Meridional Arcs," and lay it off (C) above and below the central parallel; and with the same distance as radius, strike arcs D D D D above and below from near the extremities of the perpendicular B. With a well tested straight-edge draw lines E E through the north and south minutes on the central meridian, and tangent to the two arcs D D, to the right and left. This gives three parallel lines perpendicular to the central meridian.

From the same Table VI, from under the head "Lengths of Arcs of the Parallels," take out the value corresponding to the number of minutes of longitude, east and west of the central meridian, and lay off the whole distance F F′ F″ on each perpendicular, taking each distance from its appropriate latitude. Subdivide these into minutes G G′ G″.

For the areas usually covered by plane-table sheets the corrections X, for determining the abscissas from the arcs of parallels, (Table VI, head "Co-ordinates of Curvature,") are inappreciable, and may be disregarded; the ordinates Y only being used. These give the distances to be set off from the lines B E, perpendicularly towards the pole, for each minute of longitude counting from the central meridian. For ordinary field projections of scale $\frac{1}{10000}$ the ordinate of the extreme minute only need be used, and the parallel drawn a right line from the point so found to the central meridian. This ordinate H being set off on each of the parallels, the meridians are all drawn in with a fine ruling pen, then subdivided into minutes, and the parallels carefully ruled in through the points of subdivision.

The projection is verified by applying the measure of a number of minutes of latitude and longitude, and by a comparison of diagonal measurements on different parts of the sheet.

All measurements should be carefully taken from the scale with a keenly pointed beam-compass, and the marks pricked in the paper should be as light as possible to be seen, so as to insure the greatest possible accuracy.

The draughtsman is supplied with a list of triangulation points, which gives their relative distances, their latitudes and longitudes, and also the equivalents in metres of the *seconds* of latitude and longitude, according to which the points are now plotted on the sheet by measuring from the corresponding minutes. Thus in the diagram the distance J represents the seconds of latitude; K, the seconds of longitude of the trigonometrical point.

The accuracy of the plotting is tested by a measurement of the respective distances between the points with the beam-compass, these distances being also given. The degrees and minutes are then plainly marked, usually on the north and east sides of the sheet, at one extremity of each parallel and meridian, the pencil-marks erased, and the projection is completed.

It sometimes becomes necessary to base topographical work upon a detached scheme of triangulation, before the usual astronomical observations have been made. In this case the only elements given are the distances from the points to two projected arcs of rectangular co-ordinates, (which are assumed,) and the distances between the points. The projection for plotting these consists simply of axes of X and Y, so laid on the sheet that it will embrace all the points required by the surveyor, and in the manner most convenient for his work; and the points are plotted from these by the intersection of two arcs with the distances of the points from the axes as radii, either north or south, east or west of the lines of X and Y, as the plus or minus signs given may indicate. The only test is by the distances between the points, and there should be at least two from each. If the work be correctly done, a regular projection can be constructed on the sheet after it is finished and the required astronomical work is completed.

In case it so happens that for some special purpose it becomes urgent to undertake a piece of topography, when neither the data for projections nor co-ordinates are at hand, plotting by distances is the only resource left, and, of course, great care is absolutely necessary.

It has sometimes been found expedient to carry on a plane-table survey in advance of the triangulation, or where the triangulation has not yet been connected with a base. Under such circumstances it is advisable to draw squares of 1,000 or any specified number of metres on the sheet, by means of which the projection can ultimately be laid down correctly.

FIELD-WORK.—*General remarks.*—In organizing a party for field-work it is necessary to have one man to carry the table. His duty is to remain constantly with the instrument, to leave it under no circumstances; and while the topographer is at work he holds the shade to protect the chart from the glare of the sun. In some sections the labor of carrying the table is quite fatiguing, in which case another man should be employed with the shade. He should also keep the pencils sharpened, and sometimes, when a careful person, he levels the table, thus giving the operator an opportunity to glance over the surrounding country. He should always have with him a spare piece of rubber, and one or two extra pencils. Two chainmen are needed, and two or three other men with signals, hatchet, telemeter, and other working apparatus to execute various offices, as they may be required. The maximum number necessary for field-work in a plane-table party on land is five hands, and when using a boat, six. Satisfactory work has been done, however, with three, and on very rare occasions with even two men; but, of course, with less facility. More than five and an aid, when but one table is used, is unnecessary, and a less number is a detriment to rapid execution.

The alidade is carried from station to station by the chief of party, resting on the bend of his arm, or hanging easily at the side, and in handling is to be seized by the lower part of the standard, never by the telescope or rule. Some operators prefer to have it transported in the box by one of the men, and handed to them when the table is set up at a station. It usually weighs 8½ pounds; and there is a fear of its being put out of adjustment or injured by falls on rough ground, or in crossing insecure fences, if carried by hand, and a relief is afforded to the arm by being freed for a while from its weight; but carelessness in taking out and replacing it in the box so many times during the day is quite as likely to disturb its adjustments, as is also the fall of the box, or rudely setting it on the ground; and one soon becomes inured to the weight so as to feel but little inconvenience from it. The metre scale is best fastened under the clamps which hold the paper to the table, where it is close at hand ready for reference. It has been suggested that it would be an advantage to have it engraved upon the rule of the alidade. The pencils, dividers, and India-rubber can be carried in an outside breast-pocket, the points of the dividers, when not in use, being thrust into the edge of the rubber. A handy and compact arrangement for carrying the scale, pencils, &c., is a russet leather case 10½ by 2¾ inches. It is made large enough to accommodate, on the opposite sides of the scale, when it is in, three or four pencils, and the dividers protecting the points of both; the whole carried in a leather pouch 11 by 4½ inches, slung over the shoulder, the pouch accommodating also note-books for sketching, table of heights, extra pencils, and rubber; everything being at hand and well protected. When the table is set up the dividers and pencils are taken from the case and laid upon the table, and the scale drawn out as needed. Some topographers object to carrying the scale upon the table under the clamps, because it is liable to soil the paper, to drop out in passing from station to station, is not always in the most convenient place for use, and sometimes interferes with the play of the alidade.

It is well to have ready a light India-rubber cloth cover to slip over the board in case of a sudden shower, as well as to protect the paper from the dust on the roads, mud in swampy ground, or water where a boat is used in going from one station to another. The sides of the sheet where they are turned under the table and come more or less in contact with the coat of the observer, should be protected by strips of paper about four inches wide, and six inches longer than the side of table, so as to fold under it and clamp on with the sheet itself. A plan followed by some topographers is to cover the whole sheet as exposed on the table with their paper, tearing it away at those points only where they are at work, and covering again by pasting on patches as soon as finished, thus protecting as much of the sheet as possible.

The plane-table must never be rudely handled, never roughly set on the ground, nor carried heedlessly through woods or swamps; and the weight of the body or arms should never rest upon it. Instructions should be given the men that, under no circumstances, except in cases of threatened danger, should the table or instruments connected with it be touched during the temporary absence of the topographer.

Preliminary work.—As an indispensable preliminary to the operations of field-work, the topographer must assure himself of the correctness of the plotted points on the sheet, by an examination of them in the field, either by actual occupation of each one, or of a sufficient number to embrace them all in two or more lines of observation. When this has been done, and the points found correct, or properly adjusted, as shown further on, the regular survey is commenced.

It is very rare that the number of triangulation points furnished, or their positions, are such as to suffice for carrying on an extended survey without the aid of intermediate points. These are to be determined by the plane-table; and this can be done over a whole or a portion of the sheet, either before any filling in of the topography is executed, or during the progress of the work, depending much upon the character of the country and the skill and judgment of the topographer.

Sometimes, from lack of natural objects, it is found advisable to go beforehand over the country and locate signals in suitable points for subsequent determination and use. In the location of signals, either as permanent points or simply for temporary forward lines, a great deal depends upon the good judgment of the person placing them. Two purposes are to be subserved; first, the seeing of sufficient known points to give a good determination; and, second, to command a view of as great an area of country, and as many natural and artificial features for filling in the topography, as possible. It should be remarked, also, that in the course of prosecution of the regular work, no favorable opportunity must be allowed to pass for locating a signal or determining a point which may at some future time be of service. Advantage should be taken of open places in the woods commanding roads or ravines. Piers or draws of bridges, or piles, giving lines up and down streams, with precipitous or bluffy and woody banks; trees of unusual appearance in prominent positions, or bearing flags placed upon them for the purpose; points of rock, off-shore or otherwise; lightning-rods, cupolas, weather-cocks, chimneys of factories, and other peculiar and marked objects come within this category. In fact, it may be set down as a rule, that well-determined signals located at convenient distances over the sheet are more likely to be too few than too frequent.

Signal poles should be straight and perpendicular, the flags upon them adapted in color to the background against which they will be seen when observed upon, protected from cattle in settled districts by stones piled about their bases, or earth thrown up. They should also be well marked with pegs, or by measurements to neighboring permanent objects, so that in case they are disturbed their positions may be found.

It is taken for granted that some facility in the manipulation of the table is already arrived at, as well as a knowledge of conventional topographical signs, (see sketch No. 32,) and the application of them; it being merely necessary to remark that, on maps of a large scale, it is required to plumb the plotted point exactly over the station, although on the usual field scale an approximation with the eye is all that is requisite; and that all lines should be drawn lightly and carefully close to the edge of the rule with a finely sharpened hard pencil; and that in sketching one somewhat softer is used. If the table and alidade be in proper condition, the contact of the fiducial edge with the paper will be perfect throughout its whole length; and in drawing a line along the edge care must be taken to preserve the same inclination of the pencil, and to avoid a "shoulder" in the pencil itself. If the rule be at all raised from the paper at any part, still greater care is to be observed lest the point of the pencil should run under the edge and thus deviate from a straight line.

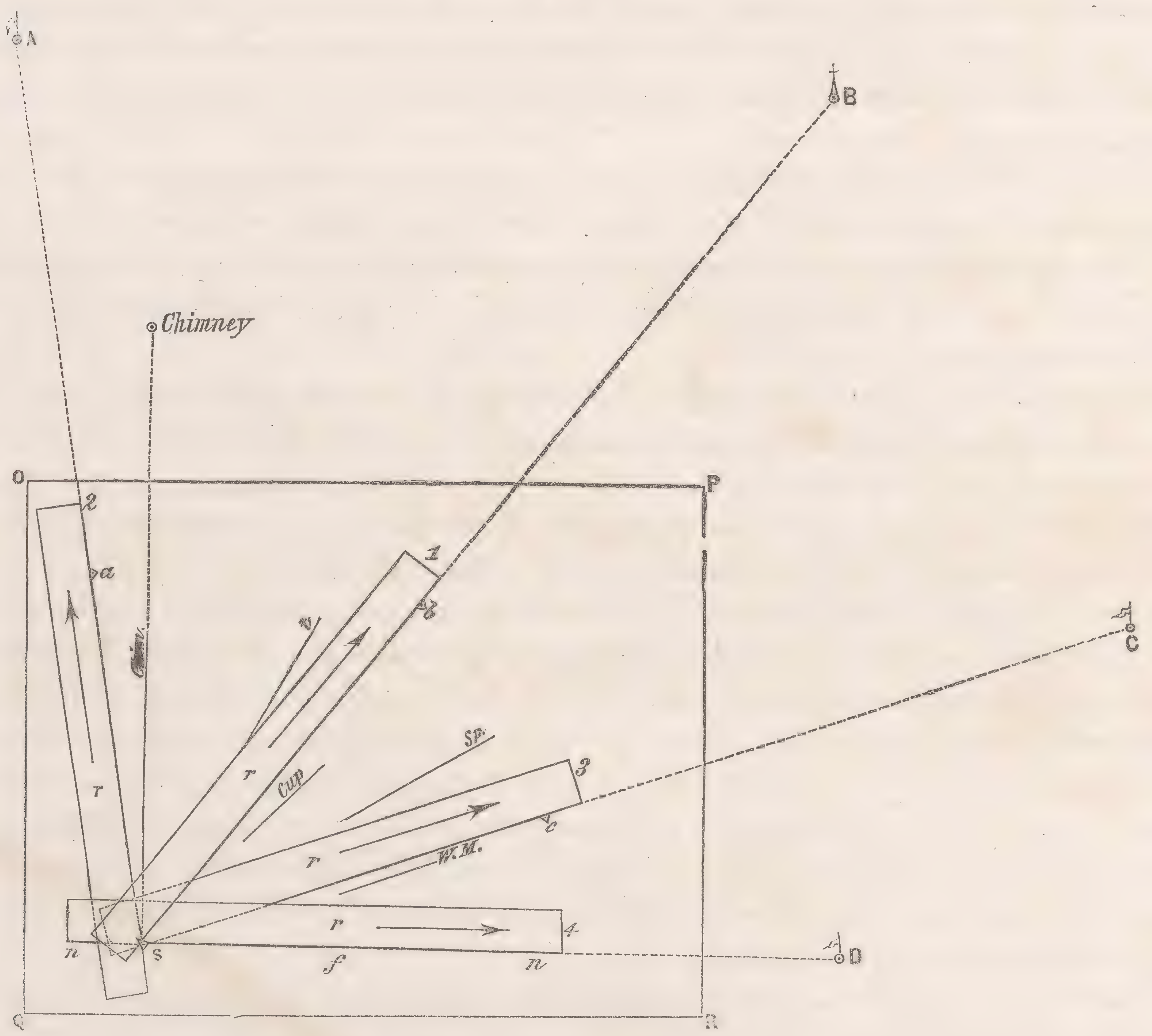
It should be well for the beginner to learn to observe with his left eye as well as the right, for obvious reasons.

The instruments should be kept scrupulously clean and free from sand or grit. An occasional taking apart of the table and cleaning with soap and water, using soft linen rags for the purpose, will be found necessary; and after being oiled and put together, it should be wiped thoroughly dry. The cleaning should not be intrusted to any person unaccustomed to the handling of instruments, and work with the table should cease the moment the presence of any foreign substance between the surfaces which play upon each other is suspected.

In observing upon signals which are not perpendicular, the sighting should be as nearly as possible upon the base of the pole.

Field practice.—Topographical points can be determined by three methods, viz: "prosection," "resection," and measured distances. In the first of these the point must be seen from two or more occupied points in suitable positions, with regard to the point to be determined; in the second it must be occupied; and in the third, there must be a direct measured line, with an established direction from the occupied point. These methods of determination, and the incidental operations which accompany them, will now be considered.

Fig. 1.



Let O, P, Q, R, Fig. 1, represent the board of the plane-table, upon which is spread the topographical sheet; the plotted triangulation point *a* upon the sheet representing the signal A upon the ground; *b*, the spire B; *c*, the signal C; and *s*, the station S; the small letters on the sheet representing the centres of the signals on the ground, which are referred to by corresponding large letters.

The table is first placed approximately level over the occupied station S, and put in position, also approximately, by the eye, so that the plotted points on the sheet are in range with the station S and the signalsr or objects they represent in the field. Then plumb the point *s* over the station S, fixing the legs of the table firmly in the ground; place the alidade upon the table so that the rule shall extend across its centre; loosen the large milled head screw projecting below the top of the stand, and by means of the levelling screws bring the bubble of the circular level on the rule to the centre. Place the alidade at right angles to its first position upon the board, repeat the operation, clamp the large screw again, and the table is level. Now free the tangent screw by loosening its clamp, place the edge of the rule *r* upon the occupied point *s* and the point *b*, the telescope being directed towards the spire B, as shown by the arrow-head in the figure, and revolve the table horizontally about its centre with the hands until B is seen in the field of the telescope;

clamp the tangent screw and turn it till the intersection of the cross-hairs bisect the top or centre of the spire B. The table is now "in position," if the plotted points be correct and the proper objects sighted. In other words, the table is "oriented" when the point observed upon and the point occupied are in the line of sight, the edge of the rule being upon the two plotted points; the one, *s*, perpendicularly over the occupied station, and the other, *b*, the station observed upon. As a test of the correctness of this, place the rule upon the point *s* again, and upon the points *a* and *c* consecutively, and if the two signals A and C are covered by the vertical cross-hair of the telescope, the orientation is assured, and the meridian of the sheet is parallel to that of the earth, all the lines joining the signals and their respective projections being also parallel.

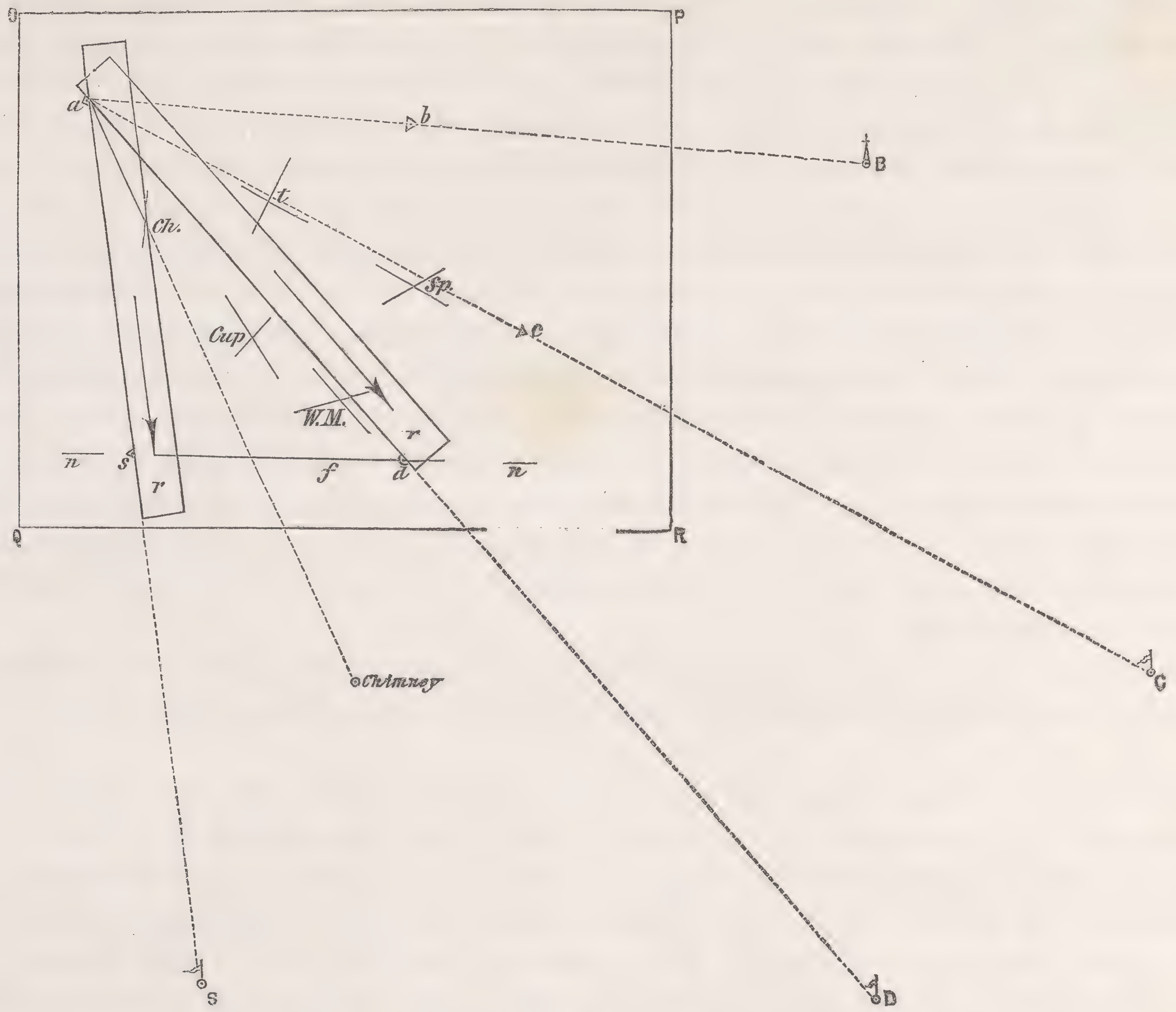
It will sometimes happen that the upper metal disk attached to the table, after it has been clamped and the tangent screw used to put the table in position, has a tendency to spring still further with a sudden movement or slight jerk, and this movement may not occur until impelled by the ordinary working about the table, and pass unobserved by the operator. This may arise from the two disks being screwed too closely together, and the faces in contact not being sufficiently oiled. It is often the source of much trouble to the beginner, and he is unable to discover the cause. It is well, therefore, in orienting the table, when this is suspected, to take hold of the edge of the board with the thumb and finger and spring it very slightly from side to side, in order that the table may settle itself in a fixed position. The cause of the trouble must, of course, be removed on the first opportunity.

The next operation is to "take the forward line" to the next point which it is desirable to occupy or determine, either some natural object which can be occupied, or a forward signal placed for that purpose, say the signal D.

The edge of the rule is placed upon the point *s* and moved about that point as a centre until the forward signal D is covered by the vertical hair, and then a line, *f*, is drawn along the edge of the rule from *s* sufficiently far to reach the estimated distance on the sheet of the point *d*, and at each end of the rule the short check lines *n n* are drawn In the same manner lines to be afterwards intersected should be drawn to such objects as it may be well to determine. To prevent confusion the ends of such lines are marked as in the diagram: *ch.*, chimney; *t.*, tree; *cup.*, cupola; *sp.*, spire; *w-m.*, wind-mill, &c. Tangent lines and lines of radiation to objects comparatively near at hand, to be chained or obtained by the telemeter, as fence corners, &c., should be likewise taken. If the station occupied be in an elevated and prominent position, its height should be observed, both as a guide for putting in the contours at the point and to serve as a point of reference in taking heights at other places, the method of doing which will be given hereafter. The necessary sketching is now done, omitting nothing that can be completed from this point; the alidade removed, the table raised, the signal put up, and the party leaves for the next station. Sometimes it is necessary to start the chain from the station to the forward signal.

When moving from one station to another it is the custom with some topographers to loosen the tangent clamp, with the idea that if the table come in contact with any object while being transported it will revolve and be less liable to injury. This perhaps is true, if the blow comes on the side of the table only.

Fig. 2.

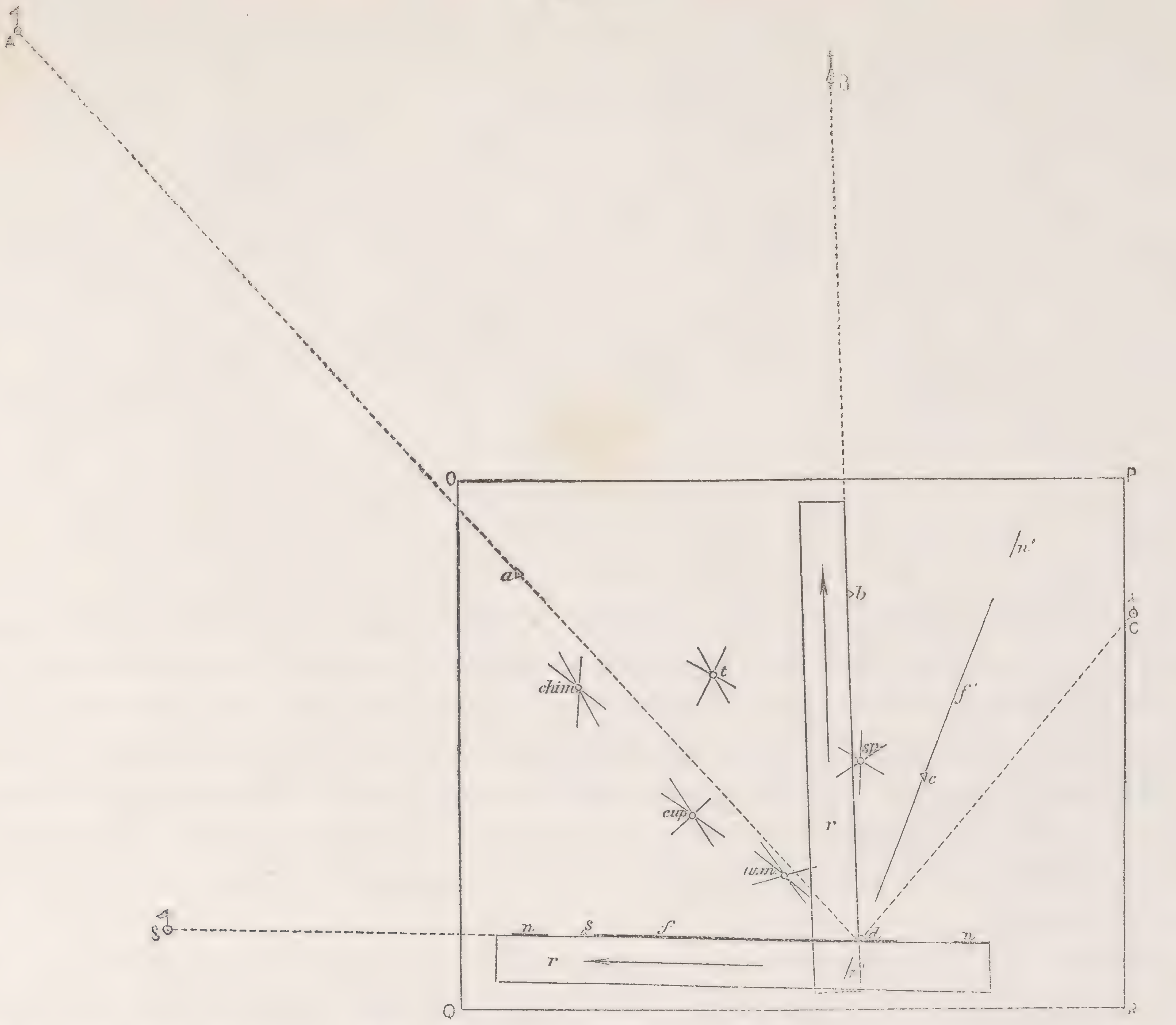


Now, let the letters in Fig. 2 be the same as in Fig. 1. The table is removed to the station A and placed over the point on the ground, put in approximate position, levelled, clamped, and loosened at the tangent screw, as at station S. The rule is then placed upon the line *a s*, the cross-hairs of the telescope directed towards the signal S, and the table brought into position, as before described. Then, keeping the edge of the rule upon *a*, direct the telescope upon the signal D, and draw the line *a d*, intersecting *f*, and determining the position of the point *d* upon the sheet, corresponding to D, and bearing the same relation in position and distance to the points *s*, *a*, *b*, and *c*, as the signal D does to S, A, B, and C. All the other objects to which lines were drawn from *s*, and which can be seen from A, are intersected and determined in the same manner. This is an example of the method of "prosection."

The necessary sketching, determination of height, &c., are executed here as at S, and, indeed, at every point occupied, it being desirable, if possible, never to occupy a station more than once.

The intersection of two lines is not, however, positive evidence of the correct determination of a point. Let us, therefore, proceed to D and again determine it by "resection" from the point B. (See Fig. 3.)

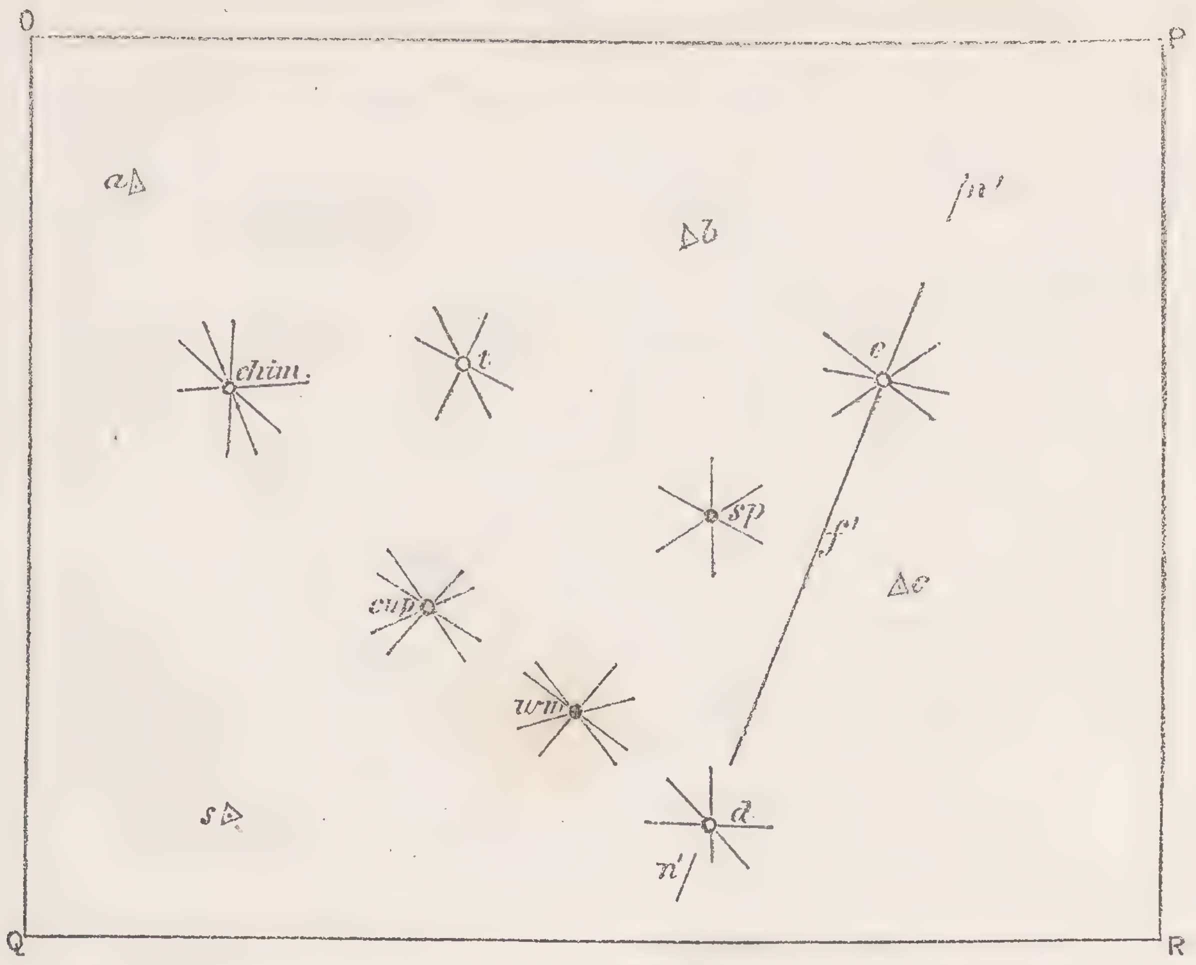
Fig. 3.



The table is placed over the point D, put in approximate position, levelled, &c., as at the other stations. The rule is then placed upon the forward line, *f*, (now called the "back line," as seen from D,) passing through the point *s*, so that the checks *n n* are just visible along the edge, and the telescope directed towards the signal S, as shown by the arrow, and the table oriented. The rule is then placed with its edge bisecting one of the plotted points, such as *b*, which will give a cleanly cut angle (the nearer 90° the better) with the line *f*, and is moved about that point as a centre until the spire B is covered with the vertical hair. A line is now drawn along the edge of the rule, crossing the line *f*. If this line intersects *f* at precisely the same point as the lines *f*, *a*, and *d*, the position of *d* upon the map is assured, and a delicate hole with the dividers should be pricked upon the sheet to fix the point, surrounded by a small circle in pencil. The point may be still further tested by resection from C. If the forward line from *s* has also been chained, the distance taken from the scale and laid off from *s* on the line *f* will afford still another test, and it is quite sufficient if it agree with an intersection where only one can be obtained.

Another forward line, *f′*, is now taken, with the usual checks, *n′ n′*, to the next desirable station, and lines of prosection are also drawn from *d* upon the chimney, wind-mill, cupola, tree, and spire previously observed, as they appear in the telescope, in succession from left to right, and their positions definitely fixed upon the map, pricked through and marked; and these being well determined, can now be used for the determination of other stations. New lines to such other objects as may be thought necessary should be taken, as well as tangent lines, and then follows the sketching to fill in the details about the station.

Fig. 4.



The table is now removed to E, Fig. 4, (which it was thought unnecessary to mark on the figure,) through which the forward line from *d* is supposed to pass, and is placed over the station; and the point *e*, representing the projection of the signal E upon the map, is determined by resections by the use of the line *f'* and the points *s*, *a*, *b*, and *c*, although the latter two are not absolutely necessary. The spire and tree may also be used for this purpose. Those points which, owing to acute intersections, have been insufficiently determined, as the chimney, cupola, and wind-mill, are again intersected. Other prosecting lines are taken from *e* upon other points which present themselves, the necessary sketching made, and a new forward line taken to the next station.

During all these operations occasional recurrence should be had with the alidade to some established point to assure the immobility of the table, or to correct any deflection from the true position which may have taken place.

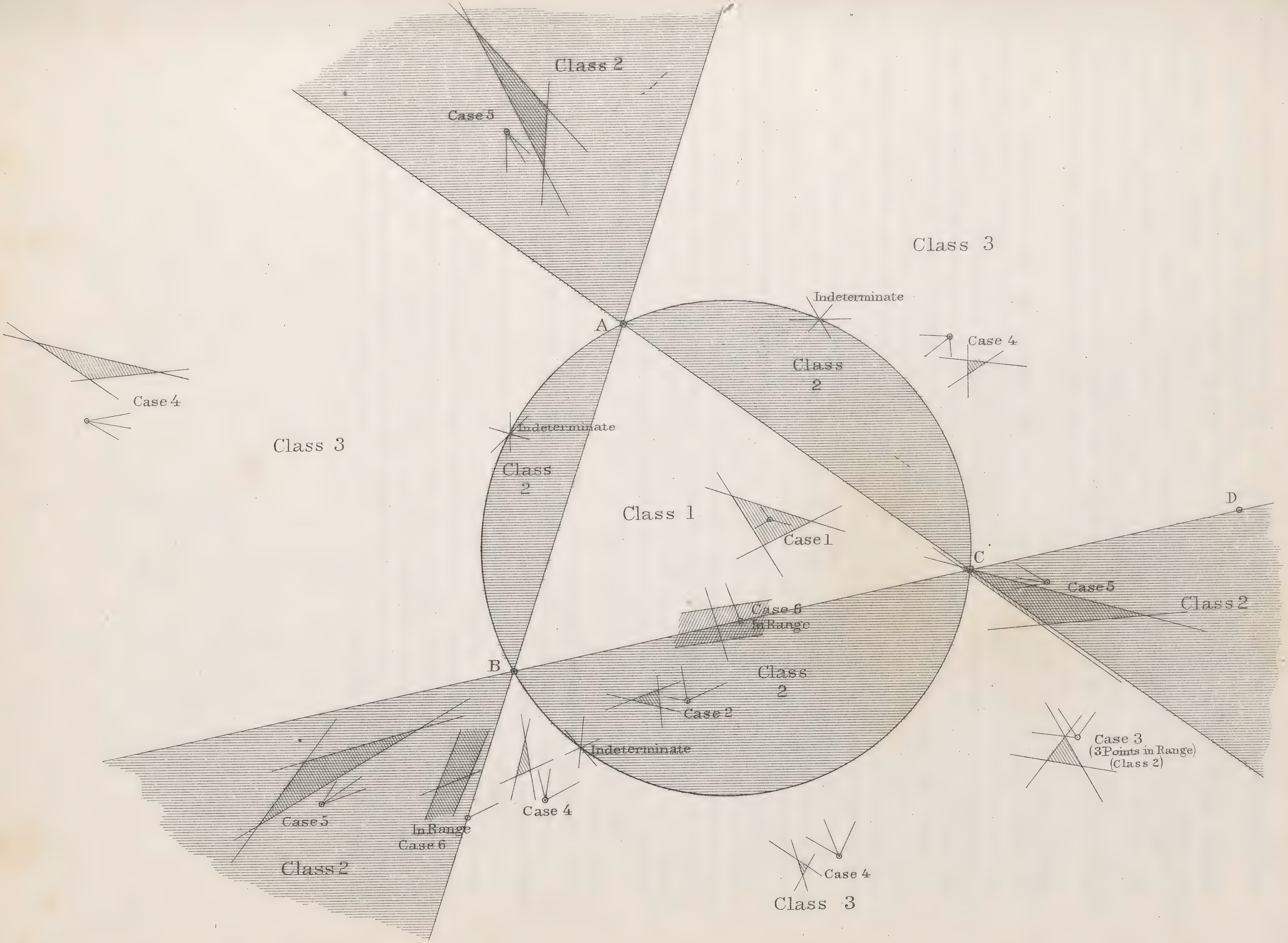
If upon going to a forward signal or object to which a line has been taken it is found that it cannot be occupied, or that it is in such a position that a sufficient number of points cannot be seen from it, or, for any reason, it does not answer the desired purpose, a point in range between the two stations, or upon the prolongation of the line connecting them, can be occupied. Getting into line between two stations is performed by two persons standing facing each other, about thirty metres apart, and as nearly on the line as possible, one of whom sees the back and the other the forward signal. Each then moves alternately to the right or left, as directed by the other, until each signal is in line with the person whose back is towards it, as seen by the person facing it. The table can then be readily placed anywhere on the line. A position for a point beyond the forward signal may also be found by simple alignment with the two signals.

When by accident in drawing a forward line from an occupied point, near which upon the sheet is plotted another or several other points, the rule is not set upon the point occupied, and the error is not manifest until the forward signal is reached, instead of going back to take the line over and draw it from the last station, it can be constructed by drawing from the correct station a parallel to the false line.

Points and lines.—The accuracy of the work on the topographical sheet is primarily and mainly dependent upon the correct determination of points, and a want of an exact knowledge of the capabilities of certain points already determined to ascertain the observer's position upon the sheet, as well as the positions of other points, is one of the greatest sources of trouble and error to a beginner. When a survey is commenced with slightly faulty points, and uncompensated as the work proceeds, the scale upon which it is executed becomes variable, and consequently erroneous.

When, as we have seen, a triangulation point is occupied, and lines drawn from a number of other plotted points with the table in position intersect perfectly at that point, the position is assured; but when they do not thus intersect, the cause of the difficulty may be found either, 1st, in errors of triangulation or computation; 2d, in a faulty projection or plotting of the points; or, 3d, in the unequal expansion or contraction of the paper. The first two, when at all great, can only be corrected by a revision of the work of triangulation and projection; and the latter, if not sufficiently large to warrant an entire rejection of the sheet, can be remedied only by the judicious action of the topographer, with the plane-table, in the field.

When the points disagree within quite moderate limits, the practised hand can, by distributing the error among the points in the proportion of their distances from the occupied point, so reduce the effect of the sum


Class 2
Case 5
Class 3
Indeterminate
A
Case 4
Class 2
Case 4
Indeterminate
Class 3
Class 2
Class 1
Case 1
D
C
Case 5
Class 2
Case 6
In Range
B
Class 2
Case 2
Indeterminate
Case 3
(3 Points in Range)
(Class 2)
Case 4
Case 5
In Range
Case 6
Class 2
Case 4
Class 3

of these distributed errors on the position of the occupied point that he may be safe in considering positions determined from his point, so corrected, as more accurate and trustworthy than the plotted points themselves, and use them as such. A maximum error of twenty metres on a scale of $\frac{1}{10000}$ can generally be reduced at the point of intersection to an almost, if not quite, imperceptible quantity.

The topographer should be very chary in rejecting points as unfit for use. No matter what the apparent disagreement may be, one should not hastily throw aside one set of points and accept another because one set *appears* to agree and the other to disagree. But the positive occupation of a series of points of whose accuracy you thus become sure, and of another series of whose inaccuracy you are equally satisfied, renders the preference of one set over the other at times not only permissible but obligatory. It should always be remembered that absolute and careful investigation in the field, and close examination of the projection, plotting, and data of triangulation ought to be made before any point or set of points is condemned.

THREE-POINT PROBLEM.

It is often expedient to set up the table in position at an undetermined point without any back line on which to set. With three signals in view whose positions are projected on the map, the table can be oriented and the point determined by means of the well known "three-point problem."

The table is brought into approximate position by the eye or declinatoire, and, not being properly oriented, the lines drawn from the three projected points will not intersect in one point, except when all four are on the circumference of a circle. In this case the "two-point problem" is available. Except in this case, however, the lines will form a small triangle, called the triangle of error, or two of them will be parallel, intersected by the third. The position of the true point can then be determined geometrically from these several intersections, and is always at the point of intersection of arcs of circles drawn through each two points and the point of intersection of the lines drawn from them; but the construction of these arcs is inconvenient in the field. More practicable modes of locating the point sought will be given in their order.

In the classification given below, based upon the locality of the true point in relation to the triangle of error, the triangle formed by the three fixed points is called the *great* triangle, and the circle passing through the same points, the *great* circle.

Class 1.—When the point sought falls within the great triangle, the true point is within the triangle of error. (Case 1.)

Class 2.—When the point sought falls within either of the three segments of the great circle formed by the sides of the great triangle as chords, (Case 2,) or without the great circle and within the sector of the opposite angle of either angle of the great triangle, (Case 5,) the true point is on the side of the line from the middle point opposite to the intersection of the lines from the other two points. This also includes Case 3, where the three fixed points are in a straight line, in which case the points are considered as being in the circumference of a circle of infinite diameter, and the true point always lying in one of the segments of the great circle.

Class 3.—When the point sought falls without the great circle and within the sector of either angle of the great triangle, the true point is on the same side of the line from the middle point as the intersection of the lines from the other two points. (Case 4.)

In case the point sought falls on the range of any two of the points, and the table is deflected from true position, the lines from the two points will be parallel, intersected by the line from the third point. But this range can always be determined by alignment, the table set in position on the range, and the point occupied determined by resection on the third point. (Case 6.)

In case the point sought falls *near* the range of any two of the three points, the lines from the two points are so nearly parallel that their intersection falls off the table, but the relation of the true point to the triangle of error is in no way changed.

The accompanying diagram, by E. Hergesheimer, of the Coast Survey, shows the fields embraced by the classes given above, also the location of each of the cases included in those classes.

A point on the circumference of the great circle being indeterminate, it is apparent that a determination should never be attempted in close proximity thereto.

The following cases are believed to include all possible conditions of the relation of the position of an undetermined point to three fixed points. The surveyor is supposed to face his signals and the directions right and left given accordingly:

Case 1. (Figure 1, Plate 31.)—When the point sought is within the great triangle the true point is within the triangle of error.

a b c are the projected points, and *ab ac bc*, the false intersections from them forming the triangle of error.

Rule.—If the line from any one of the points falls to the right of the intersection of the other two, turn the table to the left, and if to the left, turn it to the right.

When the point sought is without the great triangle the true point is also without the triangle of error, and is situated to the *right* or *left* of it, according as the table is out of position to the *left* or *right*.

CASE 2. (Figure 2, Plate 31.)—When the point sought is without the great triangle and within the great circle, the true point is without the triangle of error, and the line drawn from the middle point lies between the true point and the intersection of the other two lines. This also includes Case 3, (Figure 3, Plate 31,) which rarely occurs in practice where the three points are in a straight line.

Rule.—If the line from the middle point is to the right of the intersection of the other two, turn the table to the right, and if to the left, turn it to the left.

CASE 4. (Figure 4, Plate 31.)—When the point sought is without the great circle, and the middle point is on the far side of the line joining the other two points, the true point is without the triangle of error, and upon the same side of the line from the middle point at the intersection of the other two lines.

Rule.—If the line from the middle point is to the right of the intersection of the other two, turn the table to the left; and if to the left, turn it to the right.

CASE 5. (Figure 5, Plate 31.)—When the point sought is without the great circle, and the middle point is on the near side of the line joining the other two points, the true point is without the triangle of error, and the line drawn from the middle point lies between the true point and the intersection of the other two lines.

Rule.—If the line from the middle point is to the right of the intersection of the other two, turn the table to the right, and if to the left, turn it to the left.

CASE 6. (Figure 6, Plate 31.)—When the point sought is on the range of either two points, and the table deflected from true position, the lines drawn from these points will not intersect, but will be parallel, intersected by the line drawn from the third point; the true point is then between the two parallel lines.

Rule.—When the line from the right-hand station is uppermost, turn the table to the right, and when that from the left hand is uppermost, turn it to the left.

Practicable modes of determining the position of a fourth point by resection upon three fixed points.

1st. *Lehmann's method.* (Figure 7, Plate 31.)—This method is based upon the fact that the point sought is always distant from the three lines drawn from the three fixed points in proportion to the distances of the latter from the point occupied.

A B C are the projections of the three signals from which it is desired to determine by resection the position of a fourth point D. The table being out of position to the right, the triangle of error formed by the three lines from A B and C is *ab ac bc*. The true point occupied lies at D, being at the intersection of the circles AB *ab*, AC *ac*, BC *bc*. Now, if perpendiculars be drawn from D to the lines drawn from A B and C we shall have

$$Da : Db :: DA : DB \text{ or } Db : Dc :: DB : DC.$$

The relative distances of the point occupied from the three signals must be estimated and the point located in reference to the three lines from A B and C accordingly.

Netto's method. (Figures 8, 9, and 10, Plate 31.)—This method of determining the true position from the false intersections is ingenious and of much practical value.

The table not being properly oriented, and having resected upon *a b* and *c*, we have the triangle of error $e\ e'\ e''$. Now, by the Lehman method, judge of the position of *d*, (the point sought.) Set the alidade on *db* and revolve the table so that the line of sight passes the signal B. Resect again on *a b* and *c* and we have the triangle of error $g\ g'\ g''$. Join *e* and *g*, and through both points draw parallel lines *i i* and *k k*. Lay off $ei = ef$ and $gk = gh$. Join *i* and *k* and the intersection *l* lies in the line of sight from the true point to the middle point *b*. Set on this line, resect upon *a* and *c*, and *d* is the point sought.

If the two triangles of error are situated on the same side of the true line of sight to the middle point, the parallel lines are set off on one side of *eg* only.

The triangles of error $e\ e'\ e''$ and $g\ g'\ g''$ are always similar $\angle g''=\angle e'$, $\angle g'=\angle e''$, $\angle g=\angle e$, and as the two points *e* and *g* are always in the circumference of the same circle, if the table is deflected equally on the opposite sides of the true line of sight to the middle point, the triangle of error will be equal and $ef= gh$. On the true line of sight *gh* and $ef=o$.

In the triangles gkl and eil, ii and kk being parallel, $\angle g = \angle e$, $\angle l$ is common, therefore $\angle k = \angle i$ and the triangles are similar, and $el : gl :: ei = ef : gk = gh$.

(Figure 9, Plate 31.)—The point sought (d) must lie in the circle passing through aec, and also through agc. Draw the circle $a\ g\ d\ e\ c\ s$, join s with e and g, then we have

$\angle dse = \angle dce$ and $\angle dsg = \angle dag$

$\angle dce = \angle dbe''$ and $\angle dag = \angle dbg''$

Therefore $\angle dse = \angle dbe''$ and $\angle dsg = \angle dbg''$

also se parallel to bc'' and sg parallel bg''

and the triangles sle and blf are similar,

and the triangles slg and blh are similar;

from which we get $le : lf :: ls : lb$

and $lg : lh :: ls : lb$,

also $le : lf :: lg : lh$ and $le : le - ef :: lg : lg - lh$

that is $el : ef :: gl : gh$ or $el : gl :: ef : gh$.

The amount of the angle at l is always an indication of the value of the determination of the point sought. The more obtuse the angle the better the determination.

BESSEL'S METHODS.

Bessel gives two methods, both based on the same principle.

First method.—(Figures 11, 12, and 13, Plate 31.)

Let a b and c be the projections of the three points observed upon, and ab bc ac, the triangle of error formed by resection upon them when the table is not in position. Lay off bc' on $ba = bc$, extend bc and lay off $ba' = ba$. Call the angle at the intersection $ab = x$, and that at the intersection $bc = y$. At a' lay off toward you $\angle ba'e = \angle y$, and at c' in the same direction $\angle bc'e = \angle x$. The lines so laid off will intersect in e, which lies in the line of sight through the middle point b and the point sought, (d.) By resection upon a and c, the position of the point on this line is fixed.

The solution of this is as follows, (Figure 14, Plate 31,): Lay off at a the angle $bae = \angle bdc$, and at c $\angle bce = \angle bda$, drawing the line bc, $\angle ebc = \angle abd$ and $\angle eba = \angle cbd$. Produce bc to f, so that $bf = ba$, and draw fg parallel to ce. Lay bfg on ba, so that f falls on a and g on h.

Then we have in the quadrilateral $ahbe$ and $abcd$

$$\angle bae = \angle bdc,\ \angle hbe = \angle abc$$

$$hb : be :: bg : be :: bf : bc :: ba : be.$$

The two quadrilaterals are therefore similar, and hence

$\angle ebc = \angle hba = \angle abd$

and $\angle eba = \angle cbd$.

Second method.—The plane-table may also be put in position without the use of the points a' and c' (Figures 15, 16, and 17, Plate 31.)

On ac at c lay off $\angle ace = \angle x$, and at a lay off $\angle cal = \angle y$. The lines so laid off will intersect in e, which lies in the true line of sight through the middle point b and the point sought, (d.) Resection upon a and c then fixes the position of d.

The angles e and d of the quadrilateral $aecd$ make up from the construction two right angles; hence a circle may be described about the quadrilateral and we have the periphery angles

$ace = adb$

and $cae = cdb$.

This latter method, being simpler, is better than the first, but, under certain circumstances, one may be used when the other cannot. If, for instance, by the last-mentioned manner of construction the point of intersection (e) should fall outside the plane-table, it may possibly be made to fall inside by the first method. Again, if, by the latter method, the angles of intersections happen to be right angles, or nearly so, then the two plotted lines to e become parallel to each other, or nearly so, in which case the first method may be used with advantage.

The best mode of constructing the angles x and y upon ac is with the alidade; directing the line to one of the objects and observing the other object with the alidade set upon the point at which the angle is to be set off. It can also be readily done with the dividers by laying off the chord of the angle.

Should either or both of the angles set off at a and C be so obtuse that the point e falls off the table, a shorter base can be used, drawn parallel to ac, as near to b as may be necessary.

TWO-POINT PROBLEM.

The occasion may arise where it is desirable to place the table in position at a given point, from which point only two determined points are visible. This may be done by the following methods. The first mode, by J. E. Hilgard, of the Coast Survey, possesses the virtue of making no linear measurement, and demonstrates in a very satisfactory manner the power of the table in determining position by resection. (Figures 18, 19, 20, and 21, Plate 31.)

Two points, A B, not conveniently accessible, being given by their projections a b, to put the plane-table in position at a third point C: (The capital letters refer to points on the ground and the small ones to their corresponding projections.)

Select a fourth point D, such that the intersections from C and D upon A and B make sufficiently large angles for good determinations. Put the table approximately in position at D, by estimation or by compass and draw the lines Aa Bb, intersecting in d; through d draw a line directed to C. Then set up at C, and assuming the point c on the line d C, at an estimated distance from d, and putting the table in a position parallel to that which is occupied at D, by means of the line c d, draw the lines from c to A and from c to B. These will intersect the lines d A d B at points a' and b', which form with c and d a quadrilateral *similar* to the true one, but erroneous in size and position.

The angle which the lines a b and a' b' make with each other is the error in position. By constructing now through c a line c d' making the same angle with c d as that which a b makes with a' b', and directing this line c d' to D, the table will be brought into position, and the true point c can be found by the intersections of a A and b B.

Instead of transferring the angle of error by construction with the dividers, it may be done by the use of the table, in the following manner: Direct the line a' b' toward D, and on the line a b sight in a mark, not too near; then turn the table again, so that c d is directed towards D. In this position set the alidade on c, and point it to the mark, when it will make the required angle with the direction c D. Turning now the table until the alidade points again to D, it will be in position.

Another method, by E. Hergesheimer, of the Coast Survey, is as follows: (Figure 22, Plate 31.)

Two points, A and B, not conveniently accessible, being given, to put the plane-table in position at a third (undetermined) point, C.

Set up the table at the point sought as nearly in position as can be done by the eye, and resect upon A and B, intersecting the line bc at c'. The angle $ac'b$ is the true angle at the point occupied, subtended by A B, being the angle of nature actually drawn; therefore, the true point must be on the circumference of a circle passing through abc'. Construct this circle. Measure off a reasonable base, C D, at right angles, or nearly so, to bc, in either direction most convenient. Set up a signal at D, and with the alidade draw the line $c'd$. Remove the table to D, and, by means of a signal at C, (the point sought,) and the line dc', bring the table into a position parallel to that which is occupied at C. With the alidade centring on d, observe the signal B, and draw the line db' intersecting cb at b'. c' b' is the distance of the point C from B, and this distance laid off on the circle $ac'b$ as a chord from b will give c'', the true position of the point C. A fourth point may then be occupied, and by resection upon A B and C the accuracy of the determination of C verified.

Where it is possible to get the two signals A and B in range, it is easy to determine the position of a third point by a mode long practiced by topographers.

Set up the table anywhere on the range line, and, having set up a signal at the point sought, resect upon it, intersecting the range line anywhere, and, by means of the range signal and the line to it, the table may be set in parallel position to that occupied in the range, which is the true position, and the point sought may be determined by resection upon the two fixed points and their projections.

FIELD-WORK

In taking lines of intersection upon a point or object from a series of stations, when these lines do not coincide in one point, as they are usually derived from signals at unequal distances, the error should not be divided equally among them, but in proportion to their lengths.

It should be borne in mind that very short lines from a determined point—as, for instance, to the corners of a fenced road, where the table occupied the centre of the intersection of two roads—may be taken with no apparent error when the table is deflected to some extent from its true azimuth, but that in this case a prolonged line will be considerably out at its further extremity.

A long line should never be obtained by the prolongation of a short one from a back station where there is no small check line, or some other point in that prolongation already fixed.

It will be apparent that the more nearly at right angles intersecting lines cross each other, the more clearly the point will be defined; acute intersections, as far as possible, should be avoided, and, even when they are crossed by a third line at a satisfactory angle, a fourth line, or an accurately chained distance from a well-determined point, is advisable.

The necessity for dependence upon a measured line, with an established direction alone, for position is sometimes unavoidable; but, except for minor details, it should never be resorted to when other means are available Occasional checks are very important, and, in a finished piece of work, no lengthened consecutive series of chained lines for positions should be trusted without resections for test of accuracy. It is safer to combine both, unless the supply of signals is ample and they are favorably located.

A judicious use of range lines from established points, or signals, will much economize time and facilitate work.

Two range lines from well-determined points are equivalent in value to four insecting lines.

Tangent lines can only be used for determining the edges of woods, bends of streams, sweeps of shore-line, outlines of shoals, small ponds, and the outlines of other objects when in unimportant localities, and are inadmissible for any purpose in which accuracy of delineation is expected, save when they form a polygon, by which absolute convexity at all points is to be represented, and even then the points or objects should be visited and sketched, if possible.

Where the topography surveyed includes the shore-line of a body of water, the hydrographic survey of which is intended to follow the topographical work, as in the Coast Survey, it is the duty of the topographer to locate and determine the shore signals, and it is only necessary to state that they should be so placed as to furnish the hydrographic party with as many points as is desirable for the determination of positions on the water.

It is well to mark all stations occupied along or near the shore by pegs driven into the ground with stones about them, and give their positions upon the tracing furnished the chief of the hydrographic party and he can then select such as are best adapted to his use.

Natural or artificial objects along the shore, or in plain sight from the water, such as fence ends, rocks, prominent houses, and posts on wharves, &c., should be determined and marked upon the sheet. As some time may elapse between the labors of the two parties, the stations should be well secured above the wash of the tides.

Lines to buoys and other permanent floating objects should be, as far as practicable, taken at the same stage of the tide, or direction of current, or the status of the tide noted at the time of observation.

In the determination and tracing upon the chart of the low-water line, so much in its outline is generally dependent upon the direction and force of the wind that no fixed rules for guidance can be given.

The delineation of the ordinary mean low-water mark should be aimed at, and when it is beyond the reach of the plane-table, and presents no marked points for determination, or is of a character that will not admit of putting up and working the instrument—as along the swampy shores of the south, where the muddy shoals extend far sea-ward, and among the shifting quicksands of our great estuaries and bays—it must be left to be traced by the soundings and tidal reductions of the hydrographic parties.

It is always best to determine the high and low water lines, both at spring and neap tides. Having learned the range of tide the topographer will know how long he can work without error.

Where, on the occurrence of any great or unusual storm or freshet during the working season, the low-water line, which has already been surveyed is found to have changed in form or locality, it should be resurveyed, and both the old and new outlines retained on the sheet, with the appropriate notes.

As a feature which is quite interesting and important under certain circumstances to the hydrographer, low-water springs, having their origin and outlet below the high-water line, should be shown on the chart, where it can be done, in the regular routine of work. All grassy shoals should be delineated. They are always found in water scarcely agitated by waves or currents, and their shape and outline on the channel side is a very marked feature, and a good measure of the power of the current. Eel grasses should also be put upon the map, as indicating an antecedent accumulation of fine sand or soil.

Orientation by the declinatoire or compass-needle, alone, is not reliable, unless for obtaining positions for rough sketching in plane-table reconnaissance, but it may be useful as an adjunct when an operator, in default of sufficient points, desires to obtain an approximate position. It is used by placing the straight edge of the box containing the needle upon a magnetic meridian, previously traced upon the chart, and revolving the table until the needle points to O, or north, on the graduated arc in the end of the box. The magnetic meridian is roughly obtained at any well-determined station, when the table is properly oriented by the use of the declinatoire itself, the meridian line being drawn upon the sheet along the straight edge of the box when the needle points to O.

In sketching or drawing care should be taken not to lessen the size of natural objects, the scale being followed as far as practicable; but in some cases, which will be apparent, it may be desirable to enlarge somewhat, but very cautiously. The topographer should learn to draw from nature readily, and at once, without being obliged to erase or interlineate.

By working carefully at first this will be obtained in due time.

Too frequent use of the India-rubber disturbs the fibres of the paper and renders the subsequent inking less neat and clear. The drawing should be plain and distinct, so as not to be obliterated easily by the movement of the alidade over the paper, but not so dark or heavy as to blur. The object should be solely to represent accurately the surface and elevation of the country surveyed, and it should be easy and natural, and not a stiff copy of conventional signs.

Nothing should be left uncertain or indefinite, to be afterwards puzzled out or guessed at. As far as practicable all work should be drawn in the field under the eye. Sketching and plotting in the office from notes is objectionable, unless the country be near at hand for examination in case of doubt or a defective sketch or of error of chaining.

Too great care cannot be taken in the manipulation of the plane-table. There should be no pressure, and in moving the alidade both it and the arm should always be raised clear of the board, so as not to rub over the surface of the sheet.

The topographer should learn to distinguish, as a matter of economy in point of time, between the relative importance of different topographical features. While it should be the object to do all the work correctly, yet a line should be drawn between the expenditure of time necessary to a correct representation of the thickly-settled streets of a town and the bend of an unimportant creek in an obscure and out-of-the-way swamp. Experience alone can teach a proper discrimination in this respect.

CONTOURS.

If there be any feature which more peculiarly distinguishes one section of a country from another, imparting to it its most striking characteristic, and to which all other accidents of ground are subordinate, it is to be found in the inequalities or changes of the level of the surface, and it is the correct representation of this feature that calls forth the best skill and judgment of the topographer, and upon which the value of a map most materially depends.

Previous to the commencement of work, it is well to become possessed of some knowledge of the country which is to be surveyed. A rapid examination of the ground, by showing whether it lies in regular parallel ridges and intervening valleys, isolated hills, gradually sloping plains, or broken, abrupt, and rocky declivities, and whether partially or entirely open, or wooded, will suggest to the topographer the best method of operation, and enable him to form a general plan of work which will result in economy in point of time, and as a consequence will preserve the continuity of contour from day to day as the work progresses.

By keeping in view the characteristic features of the hills in the section of country under survey, the topographer will be able to give a naturalness to a sheet, which, by a mere formal, though correct, delineation by prescribed rules, he could not obtain. It is to be observed that the elevations and depressions, in their form and course, follow, or rather are a part of a general system of nature, however capriciously detached localities, or even extended areas may appear to be excepted from the general law. Where these exceptions are found they can usually be traced to some breach of or interference with this law, and will be found to be confined solely to the locality where the disturbing causes operated.

Thus the principal ridges will be found to tend in one general direction, either running parallel with the main range which lies farther off, or forming spurs at right angles to it. Along the coast the latter is generally the case, as we there usually find the spurs, or the extremity of some main prominent inland range. When a single detached hill is found, or a series of them, presenting, as is sometimes the case, so smooth and regular an outline as to be compared to half a watermelon, and apparently located without any reference either in direction or character to the other elevations of the vicinity; and so also when the ground presents the appearance of a confused mass of broken bluffs, rocky faces and cleft surfaces thrown together without any apparent regard to order or regularity, it will be found that the general delineation, when followed far enough, will show that the contours, whatever may be their local complexity and irregularity of outline, follow the same general direction as the main ridges of the sheet. Along the intermediate shores, upon islands, or long arms running far out into the sea, where the sandy knolls, or dunes and ridges, shift or change their outline under the influence of wind and tide, an exception is found which calls for careful delineation, and the peculiar and striking character and forms of these should be portrayed with all possible exactness as an interesting and useful aid in the study of a correlative branch of geodesy.

To the meteorologist and to the physical geographer the careful mapping of dunes is valuable, for however familiar the locality may be, no eye-view can discover those recurring features which are found in the map of an extended district.

If a sandy district is exposed to permanent or prevalent dry winds, travelling dunes will be found; these are distinguished from other hills by the contrast between the *fore slope,* (on the lee side,) which is steep, and the near slope, (on the windward side,) which is gradual. Successive surveys on sandy coasts, where close attention has been given to the contours of the dunes, are of great value for comparison if every detail is carefully given. Even in places where the winds are uncertain, proper contouring discovers dunes which travel along the resultant of the forces, and in the direction of this resultant the great dip of the fore slope is found. For such dunes the several slopes for different points of the compass are equally interesting

On exposed points projecting far into the sea peculiar dunes, called *galls*, are found. They are long ridges of sand, broken by slue-ways. It has been observed that sometimes these slue-ways are parallel. Correct and well contoured topographical maps of the localities where they are found would aid much in a study of this interesting subject. Contours only would discover their order and exhibit the material system, which could not be done by a representation by hachures.

The delineation of bluffs along the shore should also, for like reasons, be carefully executed, and when it is possible, a representation of its slopes should be given. Bluffs, if worn by the waves, will usually exhibit three slopes: 1st, the caving slope at the top; 2d, the talus; 3d, the apron or flat, exposed wholly only at very low tides. The caving slope is sometimes perpendicular where tertiary country is being worn away—never where old dunes are yielding. The talus is usually of selected material—stones, perhaps. The talus and flat are generally wanting in bluffs worn by currents.

As has been said, in no branch of surveying does so much depend upon skill, combined with good judgment and experience, as the faithful representation of hills over an extended and diversified area, and long practice and close observation only can give facility and accuracy in its execution.

Various methods, more or less defective, in presenting a correct idea of elevations and depressions, have been contrived for topographical surveys, but the graphic representation of the successive gradations of level by means of horizontal lines, as at present employed in the Coast Survey, gives the nearest approximation to nature which has yet been devised, and when faithfully executed must necessarily express very nearly, if not exactly, the shape and height desired.

Contours, or horizontal curves, are the outlines of horizontal sections of ground at different elevations, with designated equal intervals between their planes, delineated in their true positions relatively to each other and the rest of the map, and agreeably to the scale of the map itself, or, briefly, a contour is the curve produced by the intersection of a horizontal plane with the surface of the ground.

Perhaps contours may be described more simply as imaginary shore lines formed at stated or regular elevations, by the water which is supposed to rise successively to these elevations over the face of the country.

As each curve has equal vertical ordinates at all points, the elevation or profile of a hill, as well as a model in relief, can be constructed directly from the map when it is accurately executed on a large scale, without further field measurements.

A profile of a hill is the outline or trace formed with its surface by a vertical plane cutting the hill in any direction.

The annexed diagram shows the profile, through the line A′ B′, of the hill H, as represented on a topographical map. The full parallel lines upon the profile represent successive heights, or sections of the hill of twenty feet, and the broken or intermediate lines, *x x x*, those of ten feet.

A reference to the letters upon the diagram is all that is necessary for a full understanding of the subject; *a* is the shore line or high-water mark upon the map, *x x x* are the auxiliary ten-feet curves, *f′* the coincidence of curves upon the chart at the perpendicular face of the hill, *f* upon the section. This is the only case where contours of different heights run into each other upon a topographical plan. D′ D′ are depressions in the face of the hill represented on the profile by D, D; *d′* is a barranca or dry broken gully, and *c′ c′* a water course.

It will be plain that if we were to suppose the water to rise to a height of twenty feet above the high-water line, or to *h* on the profile, the twenty-feet curve upon the map would then become the shore line and the depression D′ would fill up and become a pond of water; and if the water were to rise to a height of thirty feet, the dotted broken line would form the shore line, and the knoll G would become an island.

Horizontal curves are drawn upon the map with the eye, after having obtained the heights, by means of which their positions are fixed, by the measurements of vertical angles with the arc of the alidade, or in detailed or special surveys with the level. Where the slope is regular and tolerably steep, the tracing of them is attended with but little difficulty; but where the rise is very gradual, giving large horizontal distances between the contours, even when the vision is unobstructed, or where the country is much broken or thrown into irregularly shaped knolls and depressions, presenting an intricate and confused variation of surface, the correct representation is, at times, very perplexing.

As in some instances, owing to the smallness of the angle to be measured, the vertical arc cannot be relied upon for close determination of heights, and it is evident that the nearer to a level a country is, the nearer it is necessary to obtain the exact elevation for the location of the contours, recourse to the level is indispensable. With the beginner the observations for elevation can hardly be too frequent, and he should constantly bear this in mind while at work, as well as the necessity for leaving frequent well-marked points of reference wherever it is practicable, or will serve a useful purpose.

When triangulation points are occupied, or positions are determined by the plane-table preliminary to the regular work—in fact, whenever any station is occupied, its elevation should be taken, as well as those of such other prominent points or objects as may be commanded from it. Then in using these in working by resection, the topographer has necessarily as many points of reference for the determination of height as he has for determining his position.

It is well, also, to get observations for heights as often as possible upon or from the plane of reference or high-water mark, and advantage should be taken, whenever it presents itself, of observing from the shore line in wooded districts upon any detached openings which may present themselves, and also upon rocks or any other natural or artificial objects upon the sides of the surrounding hills.

Where the heights of certain points have been taken by the triangulation party, or a few prominent ones have been determined by the theodolite or level, they should be used as often as possible as points of reference.

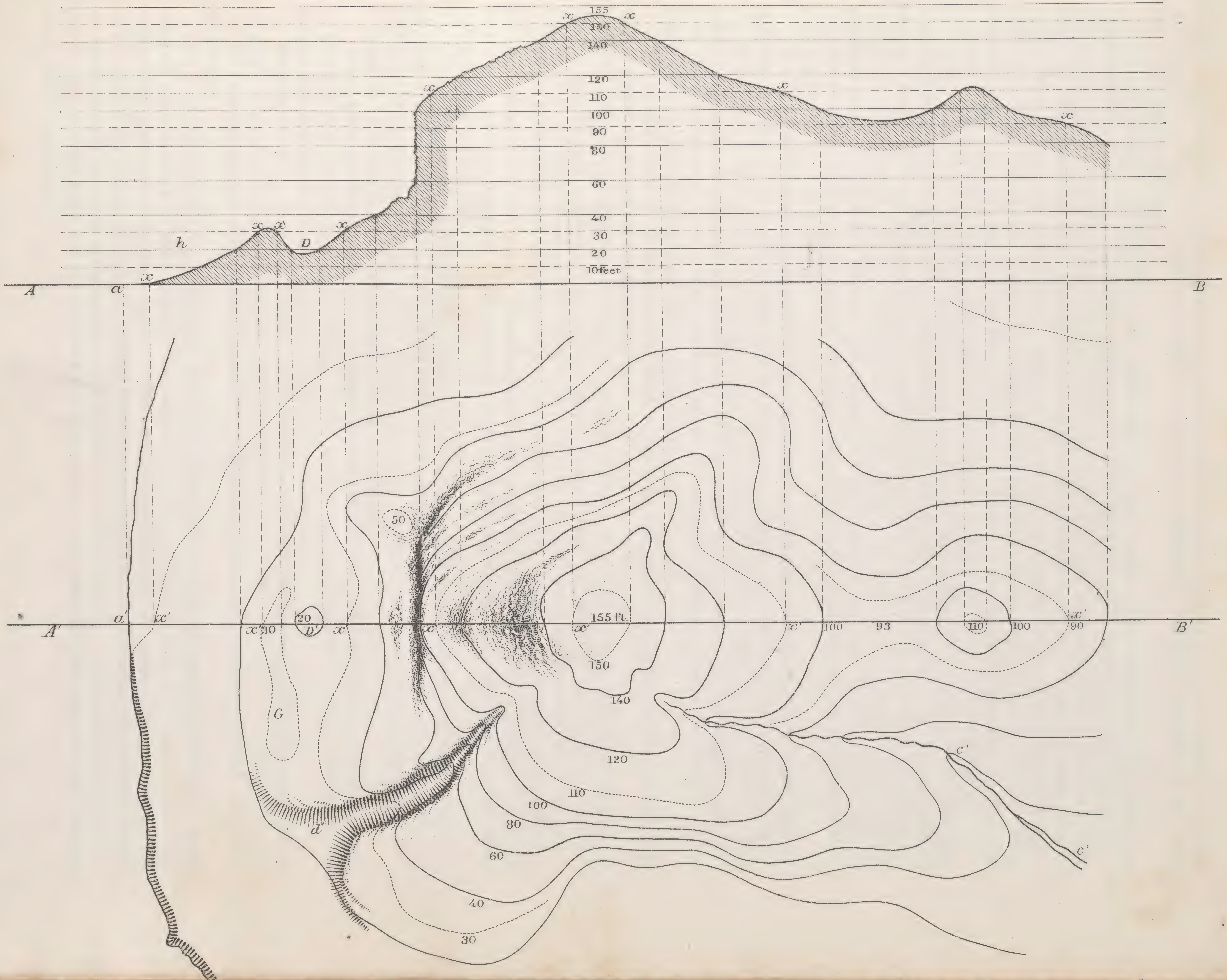
When hills are inaccessible, the determination from accessible points of both the positions and heights of objects upon them, such as trees, rocks, stumps, &c., from which the positions and courses of the contours can be determined, should be sought for, and in thick forests the roads, paths, or the dry beds of streams may be found available for the use of either the vertical arc or level.

Under certain conditions, as those of densely wooded heights and vales, inaccessible, precipitous ledges and bluffs, &c., the operations of the surveyor are limited to an almost entire dependence upon the eye alone. This cannot be relied upon, of course, and should be avoided as much as possible.

It is customary to represent on the usual Coast Survey field sheets, heights of twenty feet, but occasionally, owing to marked accidents of ground, it is deemed advisable to insert an intermediate or auxiliary contour, the practicability of doing which, however, is sometimes interfered with by the small scale of the map, taken in connection with the exceeding steepness of the declivity, giving rise to a liability of coincidence and confusion. The capability of representation in this respect depends then very much on the general nature and

Scale $\frac{1}{10,000}$

Scale of Profile 10 of height to 1 of Base.


155
150
140
120
110
100
90
80
60
40
30
20
10 feet
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h
D
a
A
B
A′
B′
a′
x′
30
20
D′
50
155 ft.
150
140
120
110
100
80
60
40
30
93
90
G
d
c′

abruptness of the hills, as, where very steep, the larger the scale of the map the greater the number of curves which can be shown, as in the French survey of Paris, where equidistant horizontal contours are drawn at every two metres of elevation.

Contours should be filled in from each station while carrying on the regular work, when it is possible to ascertain heights for that purpose, and in selecting positions for forward signals, and in prosecuting the work, reference should be had to the continuous and successive tracing of the contours on the map, both of those which are filled in *at* and those *from* the station, as this will generally prove an economy of time, and the work can be executed with more facility. When the operator is at a station whose elevation has been accurately determined, lines should be taken to objects of equal height in all directions, and marked to that effect, subsequent intersections giving their positions; this will be found of great assistance in running contours and as checks. Care should be taken in sighting to distant objects to allow for the curvature of the earth.

With regard to the method of putting in contours from the base of the hill upward, or *vice versa*, opinions differ, some preferring one course, some another, but it makes but little difference if the starting point be correct. Neither of these systems should be specially adopted, but the circumstances of the other topography should be considered, and they should be worked together to the best advantage, so as to carry on both simultaneously. It frequently happens that a piece of work is done in one part of a sheet, and then it becomes necessary to work in another, in which case the first, where heights are well determined, serves a good purpose as a check in closing.

When the work, as often happens, has been carried on in a wooded country, in a place where observations have not been taken for a long time, then the importance of coming out upon some fixed point is evident.

When this is impossible, as sometimes occurs in the filling in of the topography in dense woods, in a rolling country, and the operator is confined perforce to the roads, frequently with very short sights, and there is no check to come out upon, or when the work closes on the edge of the sheet, the use of the level in the hands of an aid, though consuming time, is indispensable.

The determination of the heights of artificial features, such as fence corners, houses, &c., as an assistance in contouring should not be neglected.

When the contour runs very near any remarkable accident of ground, as a prominent spur or indentation, on general field maps of $\frac{1}{10000}$ scale, a slight deviation above or below its true plane is admissible although it is preferable to represent it by the introduction of the auxiliary curve, as shown in the sketch.

It is very desirable that all features within the twenty feet curves, such as breaks in the ground, isolated boulders, rocks, &c., which cannot be legitimately represented by auxiliary curves, should be shown by hachures or conventional signs. When the rocks have a distinct stratification, or when cleft in certain directions, it should be indicated.

It may happen that at certain points certain small features, which are unimportant in themselves, may interfere with the development of the general form of the contours, or their introduction may tend to produce confusion; these are best omitted, but this omission should be optional only with the practiced hand. It is a dangerous precedent to give latitude in this respect to a beginner.

When there is an abrupt rise, as in low bluffs, railroad embankments, &c., not above ten feet in height, on a scale of $\frac{1}{10000}$, it should be marked by hachures always tapering downwards, and all hachures should, in their direction, follow the downward flow of water or alluvion.

Depressions of the ground in the midst of level tracts, or upon tops or slopes of hills, unless distinguished by ponds or marsh, should be marked with the letter D in red.

The distinct summits of hills should be marked in figures when characteristic or remarkable features of the country.

In measuring for heights or depressions with the alidade the plane-table is carefully levelled and firmly clamped, the telescope is directed towards the point of observation, and moved until the cross-hairs are in the same vertical plane as the observed object. The telescope is then clamped by means of the screw at the top of the arms of the vertical arc, and the central cross-hairs, at or near their intersection, are brought to cover the observed point by means of the tangent screw attached to the graduated arc. The angle read, the distance between the occupied point and the observed point measured on the map, and the height is taken from the table, which is appended.

Example.—Observations for height at an occupied plane-table station.

Stations observed.	Observed angles.	Distance in metres.	Relative height in feet of plane-table station.	Height of observed station in feet.	Height of plane-table in feet.	Corrected heights of ground in feet.
	° ′					
Shore signal, (angle of depression)	1 57	1,756	+197.4	0	4	193.4
Smith's Hill, (angle of elevation)	0 02	940	—2.0	201.3	4	195.3
Black Rock, (angle of depression)	2 13	539	+68.7	126.9	4	191.6
Mean height of station						193.4

Detail of use of table of heights.

Shore signal:

1° 50′ for 1,700 metres = 179.00 feet.
1° 50′ for 50 metres = 0.1 of 500 metres = 5.26 feet.
1° 50′ for 6 metres = 0.01 of 600 metres = .63 feet.
0° 07′ for 1,700 metres = 12.10 feet.
0° 07′ for 50 metres = .34 feet.
0° 07′ for 6 metres = .04 feet.

Total ... 197.37

In these observations three stations at least should be observed upon when practicable, and the mean adopted. On an instrument at times unavoidably subject to such rough usage as the alidade, the adjustment of the vertical arc should be frequently examined.

A material advantage in the attachment of the longitudinal level to the alidade would be found in the facility by which the instrument could then be used as a level in following outlines of equal elevation, and would be particularly serviceable on gradually sloping ground.

A formula for computation of heights, which may prove of service where no table of heights is at hand, is appended.

When, as is sometimes the case, a surveyor's level is employed, the determination of the position of the level pegs by the plane-table on the sheet is all that is necessary, and the contours can be readily traced.

Barometric heights are admissible for approximate contours in reconnaissance where a general survey only of hills or ranges is expected.

In using the aneroid barometer in ordinary reconnaissance it will suffice to allow ninety-two feet of elevation for every 0.1 of an inch fall of the index. This allowance is for a mean temperature of the two stations of 55° Fahrenheit, and will vary with the temperature.

Leslie's formula, simple and easily remembered, is a good approximation below 2,000 feet, and convenient for aneroid observations, viz: $55{,}000 \times \frac{B-b}{B+b} =$ height in feet, B being the upper, and b the lower, reading of the aneroid. This is likewise for a mean temperature of 55°.

A very convenient instrument for a tolerably close location of contours, when carefully employed, is Locke's hand-level, which can be readily carried in the pocket, it being requisite only to know the height of the eye from the ground, and for the observer to stand equally erect at all points of observation, or to hold the level at a constant height upon a measured staff.

Formula for determining heights by a vertical angle and distance.—The difference of level consists of two parts, that which arises from the angle of elevation above the horizontal plane of the station, and that which is due to the curvature of the earth. The former depends upon the angle and distance, the latter upon the distance and the earth's radius. If a' be the angle of elevation in minutes of arc, d the distance, h the height, then, as the tangent of 1′ is $\frac{1}{3437}$, we have for the first part $h = \frac{1}{3437} a' \times d$, if h and d are both expressed in the same units of length; but if d is expressed in metres and h in feet, one metre being 3.28 feet, we get $h = \frac{1}{1048}\, a'\, d$. For the fraction $\frac{1}{1048}$ we may conveniently and with sufficient accuracy put $\frac{1}{1000}$ less $\frac{1}{2}$ of $\frac{1}{1000}$, and thus find the rule: *multiply the distance in metres with the number of minutes of arc, point off the thousandth part, and subtract the twentieth part of the number thus obtained.* This will give the first portion of difference of height, whether elevation or depression.

The second term, depending on the curvature, varies as the square of the distance, and amounts to 0.22 foot in 1,000 metres, including the effect of ordinary refraction. As with the instruments under consideration extreme accuracy is not attainable, it is plain that for distances under 1,000 metres this term may be neglected. When the distance is greater we have the following rule: *Take the thousandth part of the distance in metres, square the same, having regard to the first decimal figure, and multiply by* 0.22. This term is always positive; if the first term be an elevation, it is increased; if a depression, it is diminished by the second term.

Example.—Distance = 5,500 metres; angle of elevation, 36′.

$\frac{1}{1000}\, d \times a'$ =	198.000	$\frac{1}{1000}\, d$ =	5.5
subtract $\frac{1}{20}$	9.9	square =	30.2
		multiply by	0.22
first term	188.1		
second term	6.6	second term	6.64
sum	194.7 = difference of elevation in feet.		

The above formula is near enough for distances up to ten and fifteen miles, and will not differ by as much as a foot from the result of a rigorous formula; in fact it will keep within the limits of uncertainty of the refraction itself.

Table showing the height in feet corresponding to a given angle of elevation and a given distance in metres.

Metres.	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000
Angle.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1′	0.3	0.4	0.6	0.6	0.8	0.9	1.0	1.2	1.3	1.5	1.7	1.8	2.0	2.2	2.3	2.5	2.7	2.8
2	0.6	0.8	1.0	1.2	1.5	1.7	1.9	2.1	2.4	2.6	2.9	3.1	3.4	3.7	3.9	4.2	4.5	4.7
3	0.9	1.2	1.5	1.8	2.2	2.5	2.8	3.1	3.4	3.8	4.2	4.4	4.8	5.3	5.6	5.9	6.3	6.6
4	1.2	1.5	2.0	2.4	2.8	3.2	3.6	4.1	4.5	4.9	5.4	5.8	6.3	6.8	7.2	7.6	8.1	8.6
5	1.5	1.9	2.4	2.9	3.5	4.0	4.5	5.0	5.5	6.1	6.6	7.1	7.7	8.3	8.8	9.4	9.9	10.5
6	1.8	2.3	2.9	3.5	4.2	4.8	5.3	5.9	6.6	7.2	7.9	8.5	9.1	9.8	10.4	11.1	11.7	12.4
7	2.1	2.7	3.4	4.1	4.8	5.5	6.2	6.9	7.6	8.4	9.1	9.8	10.6	11.4	12.1	12.8	13.5	14.3
8	2.4	3.1	3.9	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.1	12.0	12.9	13.7	14.5	15.3	16.2
9	2.7	3.5	4.4	5.2	6.2	7.0	7.9	8.8	9.7	10.7	11.6	12.5	13.4	14.4	15.3	16.2	17.2	18.1
10	2.9	3.8	4.9	5.8	6.8	7.8	8.8	9.8	10.8	11.8	12.8	13.8	14.9	15.9	16.9	17.9	19.0	20.0
11	3.2	4.2	5.3	6.4	7.5	8.6	9.6	10.7	11.8	13.0	14.1	15.1	16.3	17.5	18.6	19.7	20.8	21.9
12	3.5	4.6	5.8	6.9	8.2	9.3	10.5	11.7	12.9	14.1	15.3	16.5	17.7	19.0	20.2	21.4	22.6	23.8
13	3.8	5.0	6.3	7.5	8.8	10.1	11.4	12.6	13.9	15.2	16.6	17.8	19.2	20.5	21.8	23.1	24.4	25.7
14	4.1	5.4	6.8	8.1	9.5	10.9	12.2	13.6	15.0	16.4	17.8	19.1	20.6	22.0	23.4	24.8	26.2	27.6
15	4.4	5.7	7.2	8.6	10.2	11.6	13.1	14.5	16.0	17.5	19.0	20.5	22.0	23.6	25.0	26.5	28.0	29.5
16	4.7	6.1	7.7	9.2	10.8	12.4	13.9	15.5	17.1	18.7	20.3	21.8	23.5	25.1	26.7	28.2	29.9	31.4
17	4.9	6.5	8.2	9.8	11.5	13.1	14.8	16.5	18.1	19.8	21.5	23.1	24.9	26.6	28.3	30.0	31.7	33.4
18	5.2	6.9	8.7	10.4	12.2	13.9	15.7	17.4	19.2	21.0	22.8	24.5	26.3	28.2	29.9	31.7	33.5	35.3
19	5.5	7.3	9.1	10.9	12.8	14.7	16.5	18.4	20.2	22.1	24.0	25.8	27.7	29.7	31.5	33.4	35.3	37.2
20	5.8	7.7	9.6	11.5	13.5	15.4	17.4	19.3	21.3	23.3	25.2	27.2	29.2	31.2	33.2	35.1	37.1	39.1
21	6.1	8.0	10.1	12.1	14.2	16.2	18.2	20.3	22.3	24.4	26.5	28.5	30.6	32.7	34.8	36.8	38.9	41.0
22	6.4	8.4	10.6	12.6	14.9	17.0	19.1	21.2	23.4	25.5	27.7	29.8	32.0	34.3	36.4	38.5	40.7	42.9
23	6.7	8.8	11.1	13.2	15.5	17.7	20.0	22.2	24.4	26.7	29.0	31.2	33.5	35.8	38.0	40.3	42.5	44.8
24	6.9	9.2	11.5	13.8	16.2	18.5	20.8	23.1	25.5	27.8	30.2	32.5	34.9	37.3	39.6	42.0	44.3	46.7
25	7.2	9.6	12.0	14.4	16.9	19.3	21.7	24.1	26.5	29.0	31.4	33.8	36.3	38.8	41.3	43.7	46.2	48.6
26	7.5	9.9	12.5	14.9	17.5	20.0	22.5	25.0	27.6	30.1	32.7	35.2	37.8	40.4	42.9	45.4	48.0	50.5
27	7.8	10.3	13.0	15.5	18.2	20.8	23.4	26.0	28.6	31.3	33.9	36.5	39.2	41.9	44.5	47.1	49.8	52.4
28	8.1	10.7	13.4	16.1	18.9	21.5	24.2	26.9	29.7	32.4	35.2	37.8	40.6	43.4	46.1	48.8	51.6	54.3
29	8.4	11.1	13.9	16.7	19.5	22.3	25.1	27.9	30.7	33.6	36.4	39.2	42.1	45.0	47.8	50.6	53.4	56.2
30	8.7	11.5	14.4	17.2	20.2	23.1	26.0	28.9	31.8	34.7	37.6	40.5	43.5	46.5	49.4	52.3	55.2	58.2

Table showing the height in feet, &c.—Continued.

Metres.	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000
Angle.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
40	11.5	15.3	19.2	22.9	26.9	30.7	34.6	38.4	42.3	46.1	50.0	53.9	57.8	61.7	65.6	69.4	73.3	77.3
50	14.4	19.1	23.9	28.7	33.5	38.3	43.2	47.9	52.7	57.6	62.4	67.2	72.1	77.0	81.8	86.6	91.5	96.3
1° 00	17.2	22.9	28.7	34.4	40.2	46.0	51.7	57.5	63.3	69.0	74.8	80.6	86.4	92.3	98.0	104	110	115
1 10	20.1	26.7	33.5	40.1	46.9	53.6	60.3	67.0	73.8	80.5	87.2	93.9	100.7	107.5	114.3	121	128	134
1 20	23.0	30.5	38.3	45.8	53.6	61.2	69.0	76.6	84.2	91.9	99.6	107.3	115.1	123	131	138	146	154
1 30	25.8	34.4	43.0	51.6	60.3	69.0	77.7	86.1	94.7	103.4	112.0	120.7	130	138	147	155	164	173
1 40	28.7	38.2	47.8	57.3	66.9	76.6	86.3	95.6	105.2	115	124	134	144	153	163	173	182	192
1 50	31.6	42.0	52.6	63.0	73.6	84.2	94.9	105.2	115.7	126	137	147	158	169	179	190	200	211
2 00	34.4	45.8	57.4	68.9	80	92	103	115	126	138	149	161	172	184	195	207	218	230
2 30	43.0	57.3	71.7	86.0	100	115	129	144	158	172	186	201	215	230	244	259	273	287
3 00	51.6	68.8	86.2	103.2	120	138	155	172	190	207	224	241	259	276	293	310	328	345
3 30	60.2	80.4	100.5	120.5	141	161	181	201	221	241	261	281	302	322	342	362	382	402
4 00	68.9	91.8	114.8	137.7	161	184	207	230	253	276	299	322	345	368	391	414	437	460

CHAIN.

However frequent may be the number of bases furnished by the secondary triangulation, and however serviceable as a substitute in the measurement of distances the telemeter may have proved itself, we cannot entirely dispense with the chain; and as the circumstances under which its use is rendered necessary are mentioned elsewhere, it is only requisite to give a short description of the one employed in the Coast Survey. It is twenty metres long, and consists of that number of pieces of stout iron or steel wire, each piece or link being exactly one metre in length, and connected at either end with the next by being bent into an eye, through which passes a ring connecting it with the eye of the following link. For convenience of carriage these links are subdivided into lesser ones in some chains; but the advantage resulting from this is questionable, as the rupture almost invariably occurs at the joints, and multiplying them of course increases the liability to breakage; besides, the "kinking," or tendency to overlap or double, is also increased in proportion to the number of joints. On the other hand, it may be said that the bending of the links is decreased in proportion to their shortness.

At each extremity of the chain is a large ring, which slips over a staff held in the hand of the chainman, and rests upon a projecting rim of the pointed iron shoe at its base. The centres of these rings at the ends of the extended chain are the extremities of a line of twenty metres, and the points at which the pins should be inserted during the chaining.

As the strain constantly exerted upon the chain to straighten it must finally lengthen it by the "giving" of the rings, or as it may at times be shortened when the links are bent by being drawn over fences, rocks, or other unyielding obstructions, it is well to test it occasionally by a careful verification. Grave difficulties have arisen where dependence has been placed entirely upon long chained distances from a neglect of this source of error.

Adjusting screws are attached to the terminal rings of some of the chains, by which any error of length can be corrected. If a line of great length has been measured by an incorrect chain, the error in the line should be ascertained from the known error of the chain, and the plotted line corrected accordingly.

Each chain is accompanied by the usual number of pins, and a spring wire triangle for carrying them. The pins are also made of stout wire, about 18 inches long, pointed at one end, and bent into a ring at the other. It is well to attach white cotton or red flannel rags to the ring of each pin, that the rear chainman may distinguish it more readily in high grass, marsh, bushes, &c., and also at the ends of the five, ten, and fifteen metre links of the chain, for facility in counting. These rags should be changed as they become soiled.

Care should be exercised in the selection of intelligent chainmen, since it is often upon the precision of their work that the correctness of the survey in a great measure depends, and it is not always convenient or practicable for an assistant to accompany them. The better man of the two should be placed at the rear end of the chain, as he is the most responsible, and the forward man should implicitly obey his instructions. In all important places, however, such as closely settled districts, villages, and towns, in the measurement of base lines or distances upon which anything of mark may depend, an aid should go with the chain and check the records of the men.

When chaining is done in connection with the plane-table and the station is reached, the chain should be drawn sufficiently beyond and clear of the table to be out of the way, so that if more chaining is contemplated it does not have to pass the legs of the instrument.

With the class of young men usually employed as chainmen in the Coast Survey parties, it has been found safe and serviceable, after a little experience, in the absence of an aid, to have the rear man keep a chain-book, in which he notes all the crossings of high and low water, intersections of brooks, fences, roads, &c., with rectangular offsets to all reasonably accessible points on either hand, including bottom and tops of slopes, the record of tallies, and such other matters as may be needed, and may serve to assure accuracy in case of unfavorable intersections.

It is the habit with some, in obtaining short distances to comparatively unimportant objects, to trust to pacing, and practice enables one to ascertain thus the distances sufficiently close for plotting on a $\frac{1}{10000}$ scale, but these distances should never be great, and the topographer should be well assured of the accuracy of the pace. The use of the telemeter, however, may take the place of this method.

All distances to objects on either side of the chain line should be taken by offsets at right angles to it, and the book of the aid should, as far as possible, be held so that the line drawn as his guide in sketching should be in the same direction as the chained line itself, the better to enable him to draw his objects in their true relative positions.

Where great accuracy is necessary the length of a gradual slope may be measured and the angle of inclination taken with the vertical arc, with repetitions, and the measurement made reduced to the horizon by means of the following formula:

Let y be the length of the line measured upon the slope, δ its angle of inclination, and x its length reduced to the horizon; then—

$$x = y \cos \delta.$$

The excess of y over x may be computed by the formula, $y - x = 2y \sin^2 \frac{\delta}{2}$

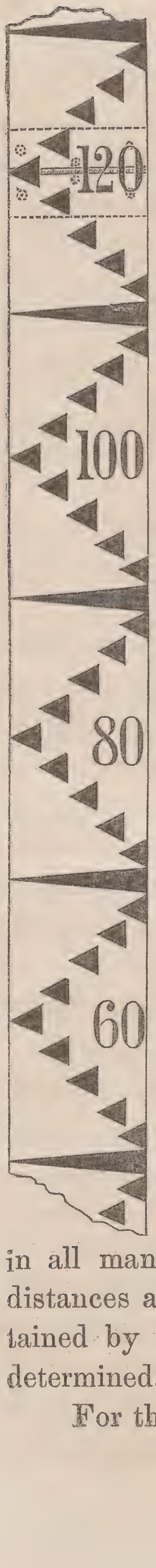
On very large scales, when parts of a metre are perceptible, Payne's tape, consisting of a narrow steel ribbon, which can be marked for minute distances, has been employed to advantage. It is convenient, also, for rapid reconnaissance in military surveys, and has been used under fire almost at double quick. Under these circumstances three men were employed, the usual back and forward chainman, with another to stand by the pins when stuck until about half the chain had passed, then, by pointing to indicate the position of the pin to the back chainman, and run forward in time to find, without difficulty, the forward pin, and also to change the pins at each tally. This tape will not stand as rough handling as the chain, and cannot be repaired in the field when broken, while the latter can lose one or more of its links and still be of service. The easy obliteration of the marks measured upon it by attrition has also been found a source of difficulty. All things considered, however, it is a very useful, compact, and handy instrument.

Many instances showing the remarkable accuracy with which the chain can be employed with the plane-table might be given from the reports of the officers of the Coast Survey; but it must be remembered that it is only to be used when other means are impracticable.

TELEMETER.

In consequence of some of the disadvantages resulting from the employment of the chain, among which are the necessity of frequent dependence for correct distances upon the chainmen, the number of persons required, the time consumed in its management, and the impediments to its use found in the features of some sections of country, another instrument, styled the telemeter, has been advantageously introduced in the topographical work of the Coast Survey.

It appears that instruments of this class were at first generally regarded by scientific men as merely ingenious inventions, and not as valuable in most respects as the ordinary method of chaining, the filling in of details forming a principal exception. From the experience of its use by the officers of the Coast Survey, however, it has been satisfactorily ascertained that the rapidity with which the details of a survey can be determined and sketched, the smaller number of men necessary to be employed, so that whatever errors may occur rest with the observer only, and the facility in using it in places where the use of the chain is impracticable, or at best difficult, render the telemeter a very important acquisition. It is not considered that it will ever entirely supersede the chain as a measuring instrument, but it is undoubtedly a facile and useful substitute under certain conditions.



The telemeter, as used in the Coast Survey, is simply a scale of equal parts, painted upon a wooden rod about 10 feet long, 5 inches wide, and 1¼ inch thick, so graduated that the number of divisions upon it, as seen between the upper and lower horizontal wires of the telescope, is equal to the number of units in the distance between the observer's eye and the rod held at right angles to the line of sight.

In all cases the telemeter should be graduated experimentally for the particular instrument and eye of the observer who has it in use.

The horizontal wires in the diaphragm of the telescope should be accurately adjusted, and the divisions of the telemeter made to correspond in length with the distance included between the upper and lower wires of the telescope at a carefully measured distance, and then divided into as many equal parts as there are units in the distance measured.

For convenience of transportation it can be hinged in the middle, and secured on the side when in use by a sliding bolt; and as it is necessary, when observed upon, that it should be held accurately at right angles to the line of sight, a small brass movable bar, with sights or a groove upon its upper edge, should be fixed upon theside of the rod at a convenient height for the eye of the rodman, and which, when in position, will be perpendicular to the plane of the telemeter and directly in the line of sight of the telescope.

The correctness of the telemeter depends upon the closeness of the reading, and the accuracy with which the rod is held perpendicularly to the line of sight.

With ordinary care an error of reading should not occur even at the greatest distance denoted on the rod. With the observations carefully made, and the reading of the rod reduced to a horizontal plane, the greatest distance given by it—as usually divided, can be relied on as practically correct. There is no sensible error at any distance greater than 20 metres and less than 260, and, generally speaking, the telescopes of the Coast Survey alidades have not sufficient reading power beyond 400 metres, but it will generally be safe to rely upon it for any distance from 15 to 500 metres, beyond which it cannot be read with accuracy for use in constructing a map on a scale of $\frac{1}{10000}$.

The telemeter has been recommended for use in a great variety of cases where it becomes necessary to determine distances, in such close filling in as the corners of streets, wharves, &c., determination of all classes of detail, in traverse, shore line, and even the establishment of positions, but in the latter it is safe only to depend upon good intersections. It has been employed, however, in all manner of detail, and is preferred by some to the chain, in all cases save on long lines, where the distances are so great that the telescope will not admit of the accurate reading of the rod, and it is maintained by some that where only a single point is to be seen positions can be readily and accurately determined.

For the reduction of the hypothenuse to the base, the following table is given:

Table for reduction of hypothenuse to base.

Angle.	Hypothenuse.				
	100 metres.	200 metres.	300 metres.	400 metres.	500 metres.
5°	99.62	199.24	298.86	398.48	498.10
10°	98.48	196.96	295.44	393.92	492.40
15°	96.59	193.19	289.78	386.37	482.96
20°	93.97	187.94	281.91	375.88	469.85
25°	90.63	181.26	271.89	362.52	453.15
30°	86.60	173.21	259.81	346.41	433.01
35°	81.92	163.83	245.75	327.66	409.58
40°	76.60	153.21	229.81	306.42	383.02
45°	70.71	141.42	212.13	282.84	353.55

RECONNOISSANCE.

The term reconnaissance as applied to topography, is a somewhat indefinite one, or rather it might be said it is very comprehensive. When there is any deviation from the closest attainable accuracy in a finished plane-table sheet, it becomes, strictly speaking, a reconnoissance map, and the rudest sketch of a country in which the features are delineated in rough approximation, which for certain temporary purposes is all that is needed, is likewise so called, so that in executing this kind of work with the plane-table there is much left to the judgment of the topographer. The amount of accuracy and closeness of detail required depends solely upon the object for which the survey is undertaken and the time and expense allotted to its completion. It is always best, however, to strive for the greatest precision which the circumstances will allow, particularly as the sheet may at some future time become available for other objects than that originally intended.

To the practical surveyor it is unnecessary to give any rules for his guidance, as his knowledge of the plane-table and of the requirements of the special work which he is called upon to perform will enable him to execute it promptly and satisfactorily. To the beginner, however, a few words on this subject, together with a statement of some of the results of the work accomplished by the Coast Survey officers, may not come amiss.

The recent war has shown in a forcible manner how little accurate information there was with respect to the topography of the interior of many of our middle and southern States, and the want of a sufficient number of topographers in the regular army was supplied, in answer to the calls of the War Department and various generals in the field, from the Coast Survey; and in almost every field of operations from the commencement of the war to its close, the plane-table was used.

Until this time very little was known, save in theory, of the value of the plane-table as a reconnoitring instrument, and it is the testimony of all the officers of these parties, as the result of their labors, that for rapidity and accuracy in the execution of military reconnaissance it is more effective than any other instrument.

The usual system adopted, in default of triangulation, was the measurement of a base with an ordinary chain and triangulating with the plane-table.

In detailed surveys for the army, where a topographer averages about a square mile a day, a chained base of from one-half to three-quarters of a mile for the survey of an area of twenty-five square miles, is found sufficient.

At Chattanooga, from two different bases of about half a mile each, plotted on separate sheets, and measured once carefully with the common 20-metres chain, the same chain being used for both measurements, after considerable intermediate plane-table triangulation carried on by two officers, two objects were determined two and a half miles apart, common to both sheets, which were on a scale of $\frac{1}{10000}$, and the discrepancy was but about 15 metres. Many other points of junction indicated this to be the maximum error. In this case the leaves were mostly off the trees, and the hills afforded good points. The sheets covered about 20 square miles each. At Nashville there was a discrepancy of about 10 metres in two miles. This would not do, of course, in finished work, but it is very close under the circumstances.

At other times, when the character of the country or the pressure of time did not admit of the measurement of a preliminary base and topographical triangulation, the work was commenced by starting from a single point, and prosecuted by linear measurement with the chain, intersections from the ends of the chained lines being taken to determine objects, which, as the work progressed, could also be used as checks upon the chaining. Where circumstances permitted, an occasional return with the chain to a back point, either to close a series of lines upon it or to start afresh, was resorted to. This work was generally carried on over roads, and the interior filled in by sketching and intersections, as far as practicable. Some of the tests in this latter work, where the operations of two officers joined, were remarkably close.

A very efficient topographical officer estimates that with the usual number of hands and a good sketcher for aid, in a country of average variety of detail, in which all the houses, prominent barns and out-buildings, streams, roads, general outline of woods, and approximate curves are to be shown, on a scale of $\frac{1}{10000}$, an area of between two and three square miles can be filled in daily, with not only sufficient accuracy for military purposes, but so that an accustomed eye with "the map in hand would not discover any marked discrepancy."

This rapidity of work, however, could not be expected in or near towns or populous districts. It is doubtful if the average work would reach more than one-half this amount.

In some thickly wooded sections, and where time is limited, it has been found advisable to run the main roads with the plane-table, and fill in with the compass, which is more rapid but less accurate than where the entire work is done with the plane-table alone. The usual method employed, where these instruments were combined, was as follows: Where the army was stationary, or moving leisurely, one main road was run with the plane-table, the operator being accompanied by assistants well practiced in the use of the compass. Upon arriving at any important road or water-course, an assistant was sent to the right and left, starting from a plane-table point, determined by the chaining, and running as far as was requisite and then returning to the main road again to repeat the operation, the compass notes, of course, being kept in a book prepared for the purpose. Prominent points determined by the plane-table were used as checks in the compass work. The intervening topography, where no compass or plane-table work had been done, was sketched in by the chief of the party, in which accurate pacing became of great service.

OFFICE WORK.

All the drawing of the topographical features of a survey upon the chart should be pencilled in the field, while they are still under the eye. Sketching and plotting in the office from notes, unless the country be near at hand for ready reference in case of doubt or a defective sketch, is objectionable. Where this is unavoidable the sketch should be transferred to the sheet as soon as possible after having been taken, while it is fresh in the mind of the person by whom it was made, and by whom, also, if possible, it should be plotted. Days which, from inclemency of the weather, are unfavorable for out-of-door work, should be allotted to this purpose, and advantage should be taken of them, also, for retouching any details of the sheet which may have become indistinct, as it is very important that they should not be left indefinite or become obliterated; for when the inking is done, as it generally is, at a distance from the field of operations, the necessity for this care is obvious. Nos. 4 and 5 pencils are good for this purpose, for which very hard or very soft and black pencils are equally unsuited.

In the inking of a topographical sheet three requisites to its proper appearance when finished should be borne in mind: clearness, neatness, and uniformity.

The lines and objects should be clean and sharply defined, nothing being left obscure or doubtful; the paper should be kept unsoiled, and erasures avoided as far as possible, and the style and strength of the drawing should be the same throughout. It is an important matter that an easy and natural appearance should be given to the map, for, as before remarked, a mere rigid adherence to conventional signs is not all that is necessary; while there should be no deviation in this respect, at the same time the draughtsman should strive to *represent the country*. There is a great difference with regard to this among topographers. Two perfectly correct charts of the same section of ground, executed by different persons, may be inked, and while one will have a stiff and ungraceful look, the other will appear artistic and natural, giving at once the impression of a sincere representation of the country surveyed.

Office work should not be commenced until the topography is entirely completed, as no inked or partially inked chart should ever be used in the field. Sometimes, for the special examination of old work, or for the insertion of some recent artificial or natural changes, this becomes necessary. There is always a risk of injuring an inked map by exposure to the weather or by using it upon a plane-table.

The inking should commence with the shore-lines, high and low water. The high-water, or shore-line proper, should, in all cases, be full and black, the heaviest lines on the sheet, and in this, as in all the rest of the ink-work, the lines of the survey should be strictly adhered to.

The topography as drawn in the field is supposed to be correct when the chart is finished, and no office amendments or changes are admissible. The low-water line is next drawn, not so full as the former, but clear, black, and uniform, consisting of a dotted line for sand and mud, and the conventional sign where it is formed by shells, rocks, or coral reefs.

Grass upon flats, or shoals covered at high tide, have no distinct continuous line to mark their limits, each being represented in its proper form and within its area by its conventional sign only, but the shape should be well and correctly defined. All objects between high and low water, covered at full tide, should be represented less boldly than the rest of the map, but not faintly or indefinitely.

The roads should next be inked, plainly and evenly, and their sides parallel, except where the survey shows a deviation from the general width. Where a road is fenced the fence should be shown by the usual sign, and where there is no enclosure a dotted line should indicate the road-side, and then should follow the fences and houses. In drawing the latter care must be taken that the corners and angles exhibit a sharp, clear outline, which adds much to the appearance of the map.

The general skeleton of the survey being now completed the contours are drawn with a bold, uniform, plain red line, without break, over all the other work, following accurately the full range of level of each of the contours on the sheet.

After this comes the general filling in, by conventional signs, of sand, marsh, grass, cultivation, orchards, rocks, hachures, &c. Some practice is needed to execute the sand-work regularly and neatly. It should never be hurriedly done, though, of course, rapidity in this respect follows practice. The lines representing marsh, and the delineation of grass on the fast land, should always run in the same direction over the whole sheet, and be parallel to the top of the sheet and the title. The appended drawing (Sketch No. 32) gives the conventional signs as adopted by and now used in the Coast Survey.

The most difficult part of the inking for a beginner is the lettering, which now follows, and for which samples are given, (Sketch No. 32.) It is expected that every topographer shall have learned to draw sufficiently well to ink his sheet in a clear and distinct manner, and letter it with some regard to neatness and graphic effect, as the appearance of an otherwise well-inked sheet is sometimes marred by careless or indifferent lettering.

The location of the names upon the sheet should be such as not to cover or obliterate any detail or feature of the survey, and the letters should be put in neatly and gracefully, and in point of size and form according to the specimens furnished. The title should finally follow, with such notes as may be necessary to explain any peculiarity of the sheet or survey. This title and lettering should, as far as practicable, be so placed that when the sheet is held with the top (usually the north or east end of the map) from you it can be easily read; in other words, as nearly parallel to the top or upper end of the sheet as the nature of the work will admit. All names well established and recognized in a neighborhood, both general and local, should be collected during the survey, and their correct orthography ascertained, and, in case of any doubtful or disputed orthography, a report should be given of any traditions or any authorities which may bear upon the subject. No illuminated or German text, old English, or what is known as "fancy printing," should be indulged in, a strict adherence to simplicity being the greatest ornament.

The minutes of the parallels of latitude and meridians of longitude should be marked in figures at the upper and right-hand ends, respectively, the degrees on the centre parallel and centre meridian only.

Where the buoys are determined by the topographer, and their names, colors, numbers, or kind are known they should be lettered upon the map.

The triangulation points should also be lettered, first being surrounded by a small circle. The magnetic meridian should be drawn with a half fleur-de-lys at its head, and the true meridian, where no projection is used, with a full one.

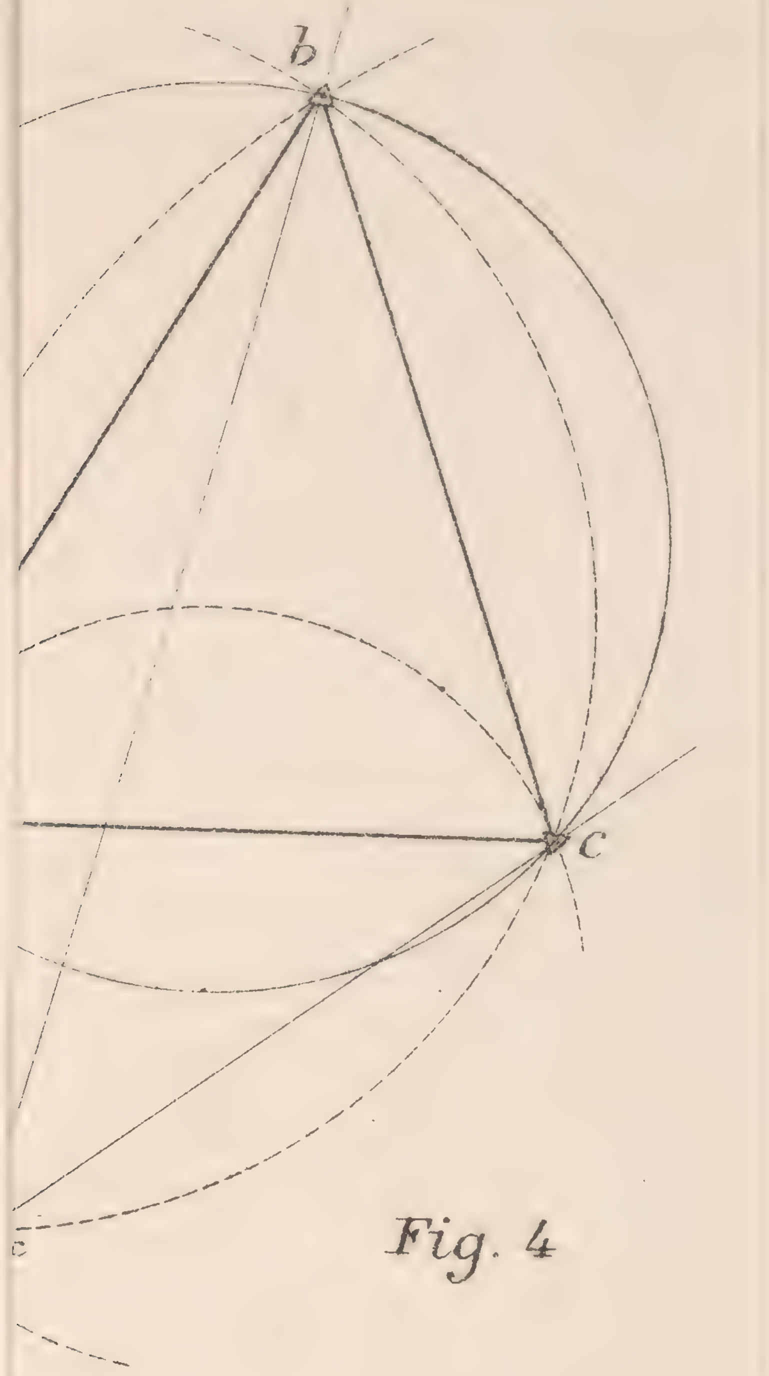
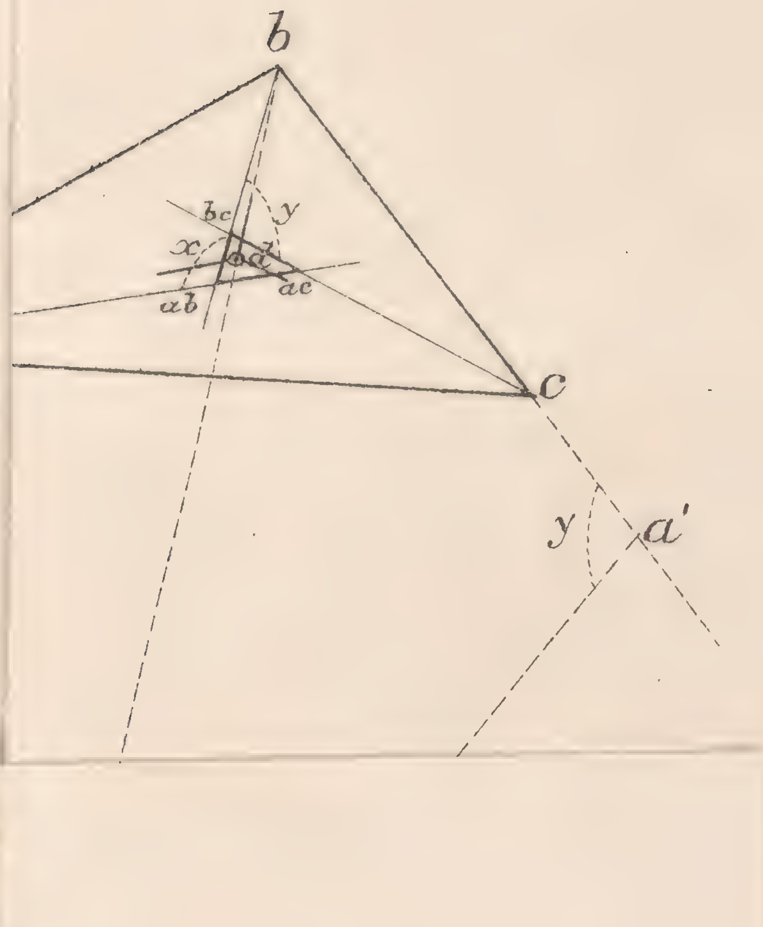


Fig. 4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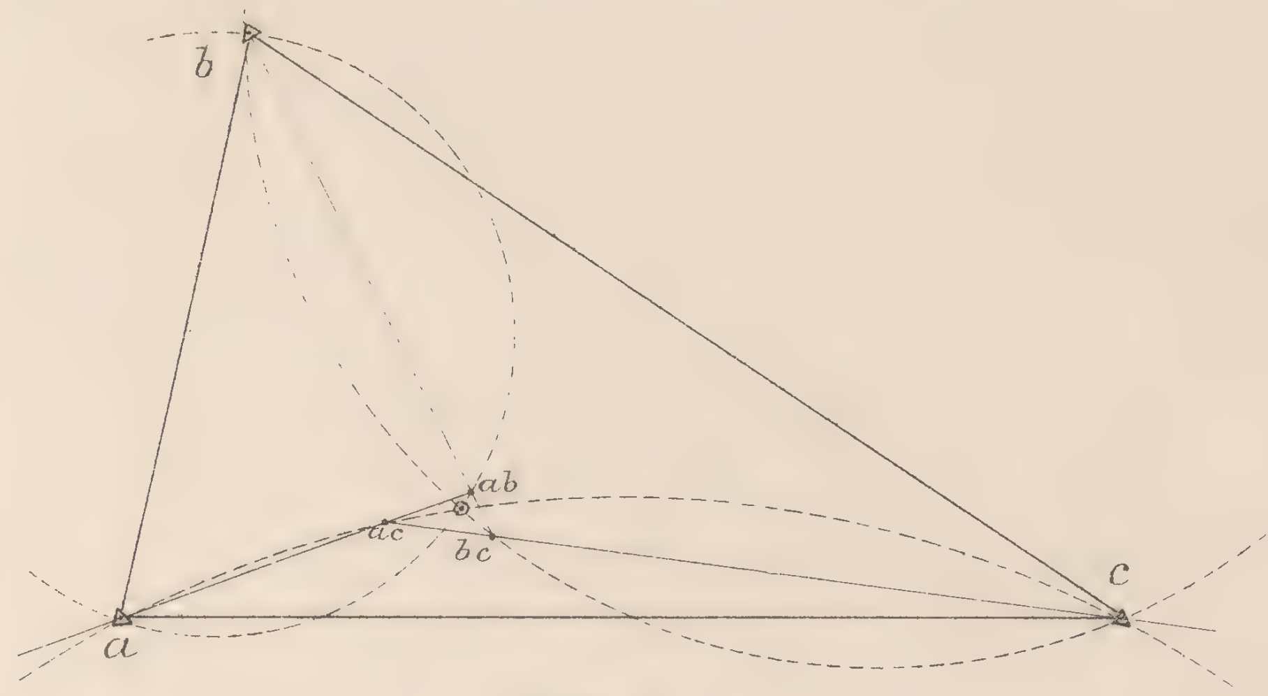

Fig. 1

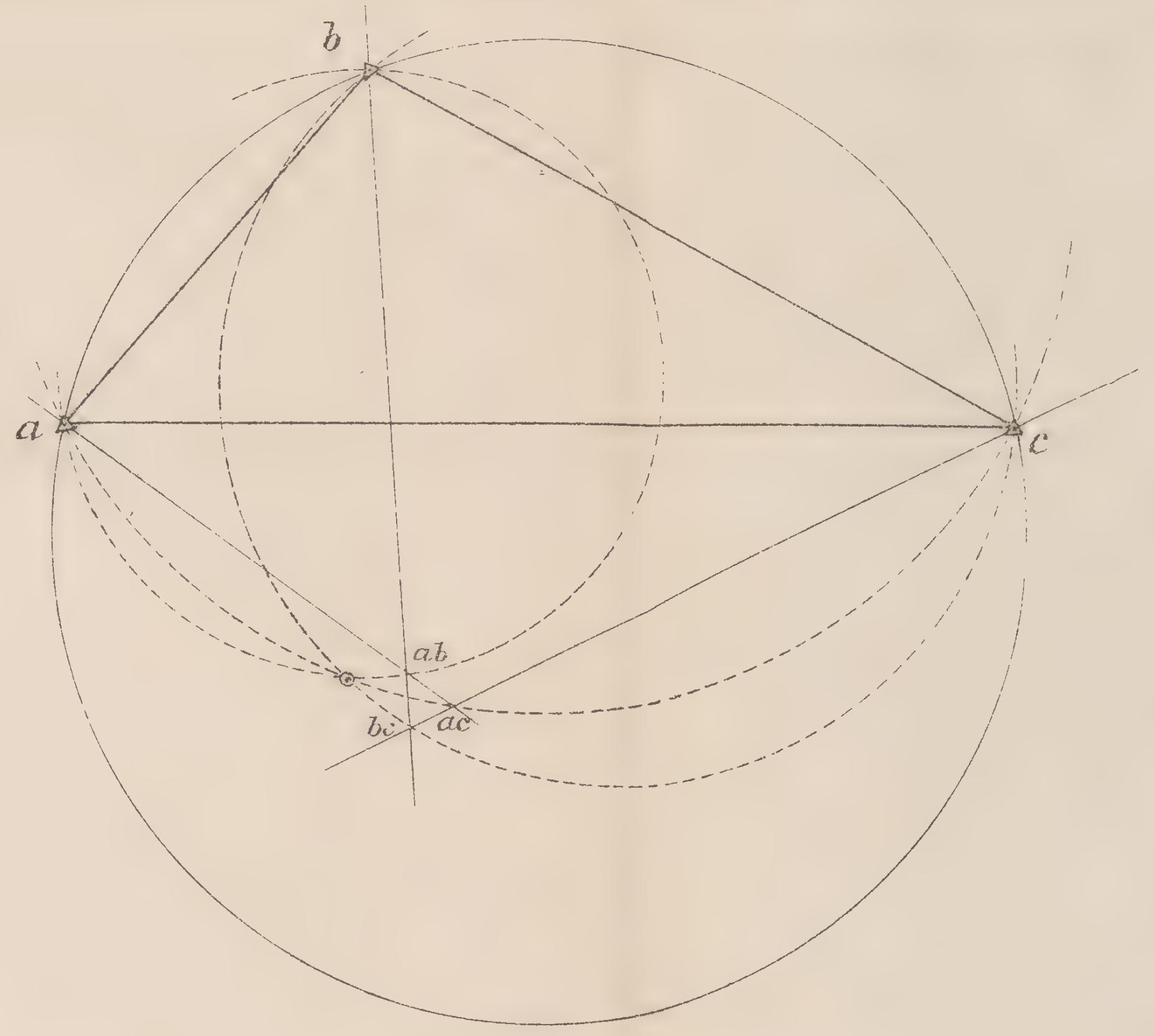

Fig. 2

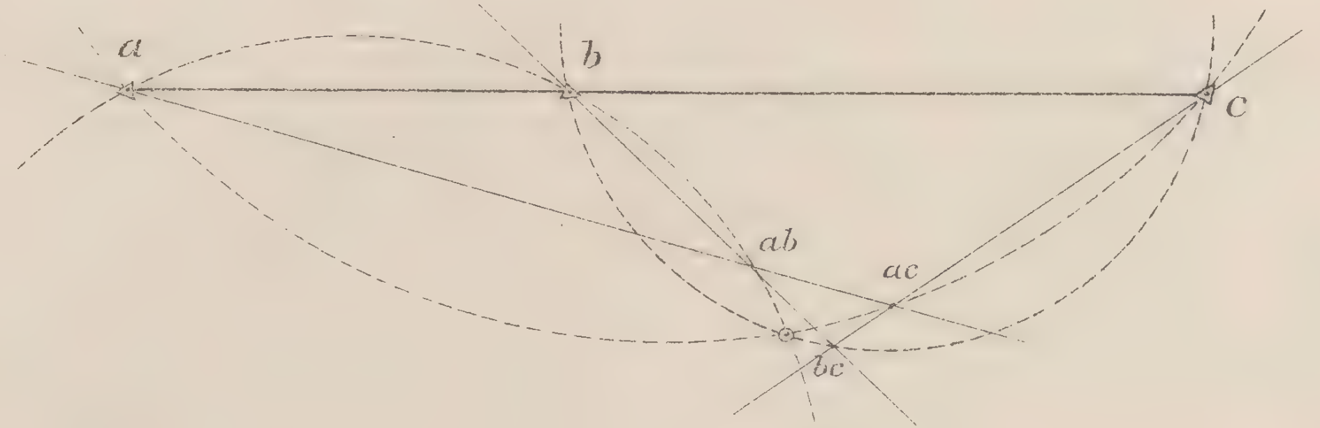

Fig. 3

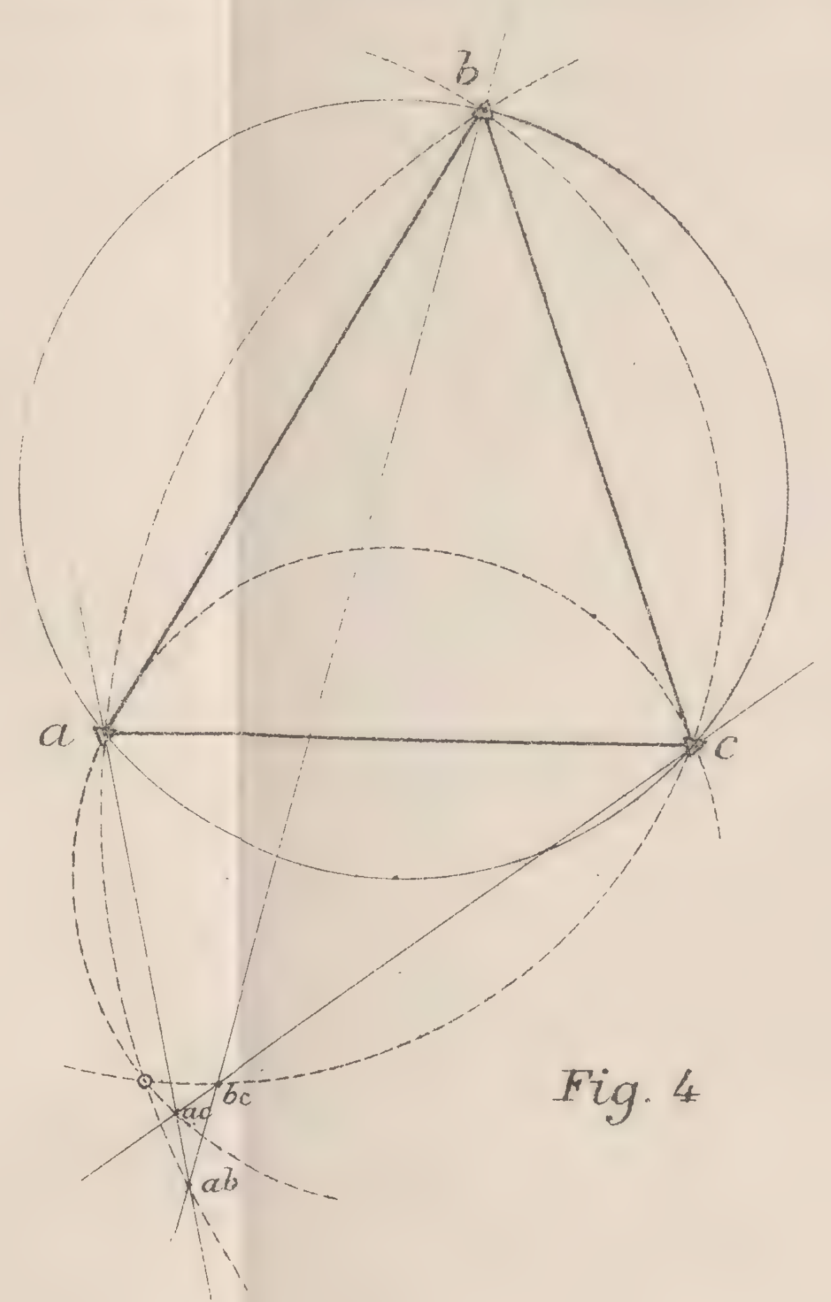

Fig. 4

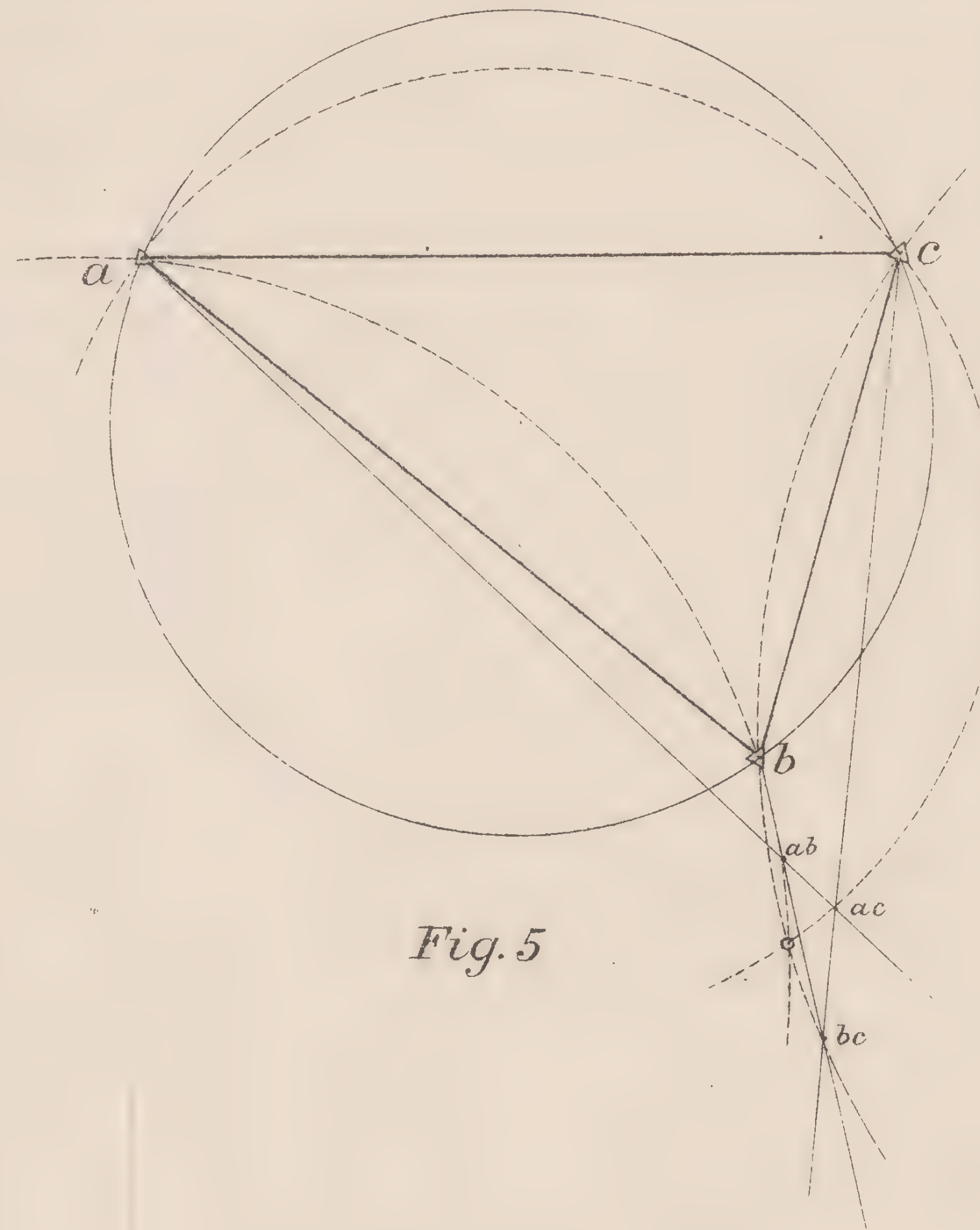

Fig. 5

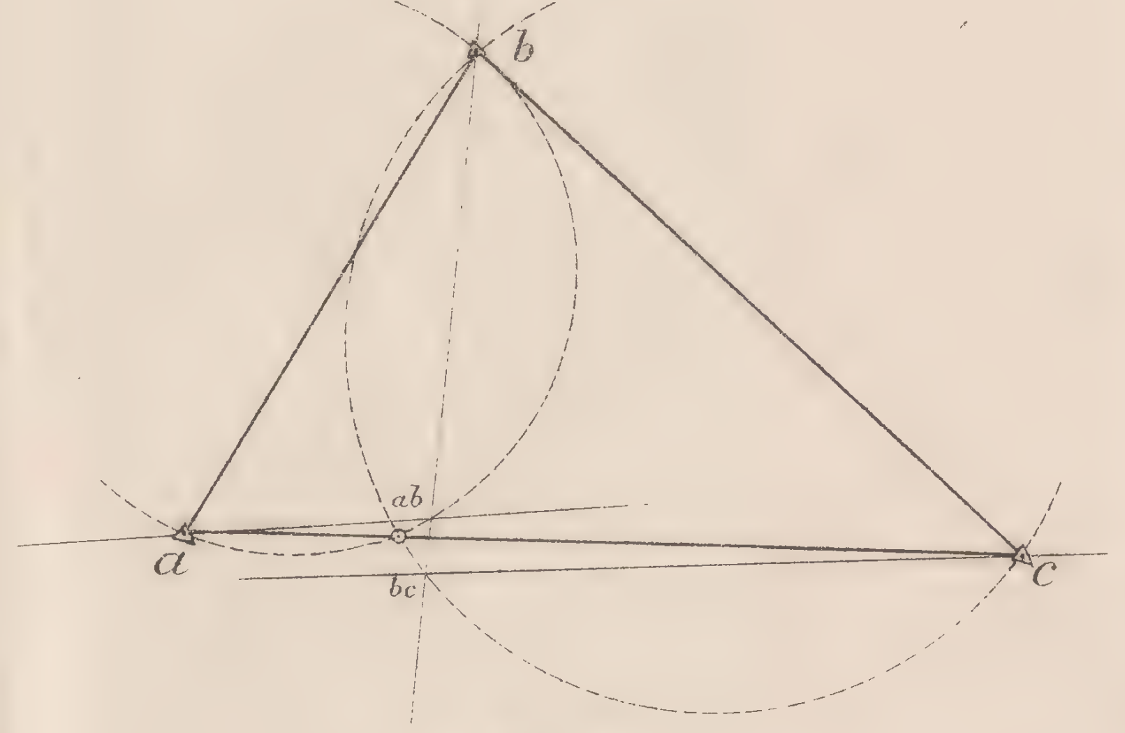

Fig. 6

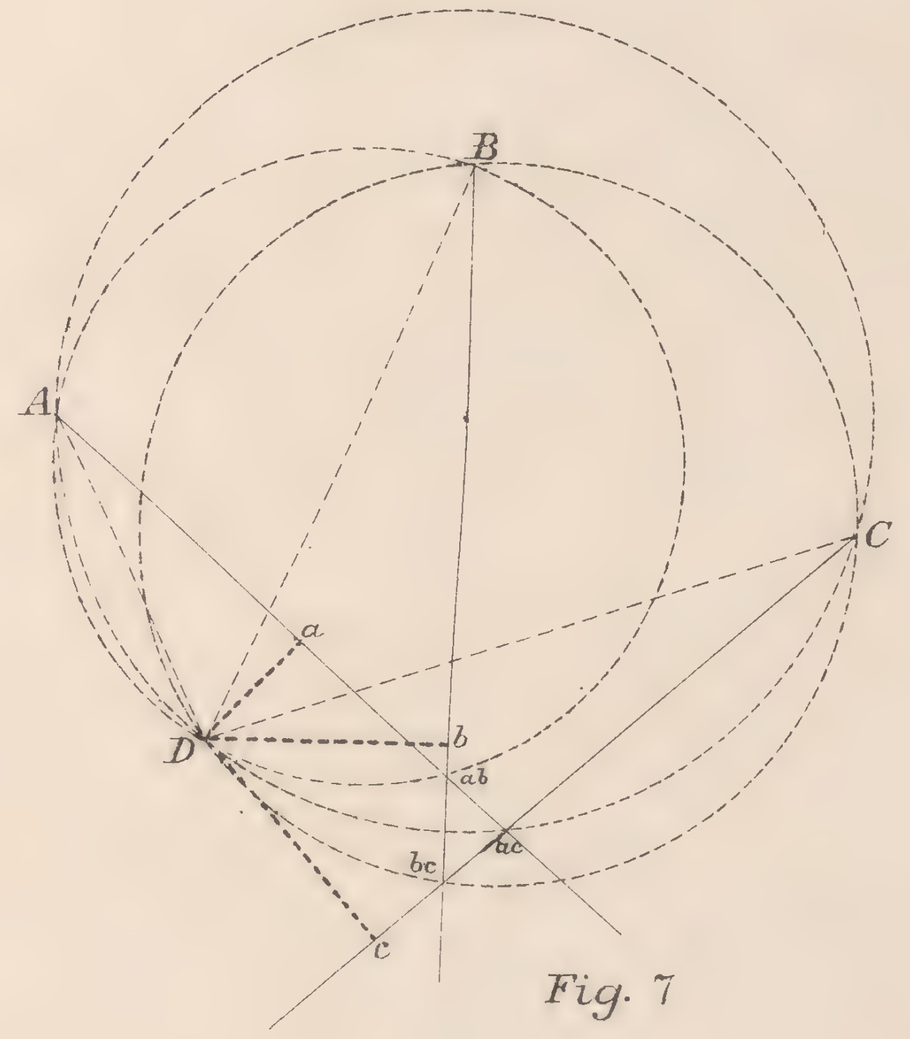
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Fig. 7

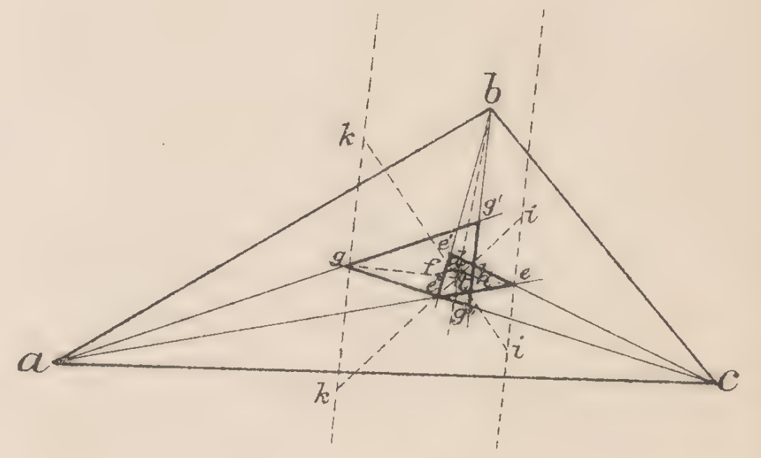

Fig. 8

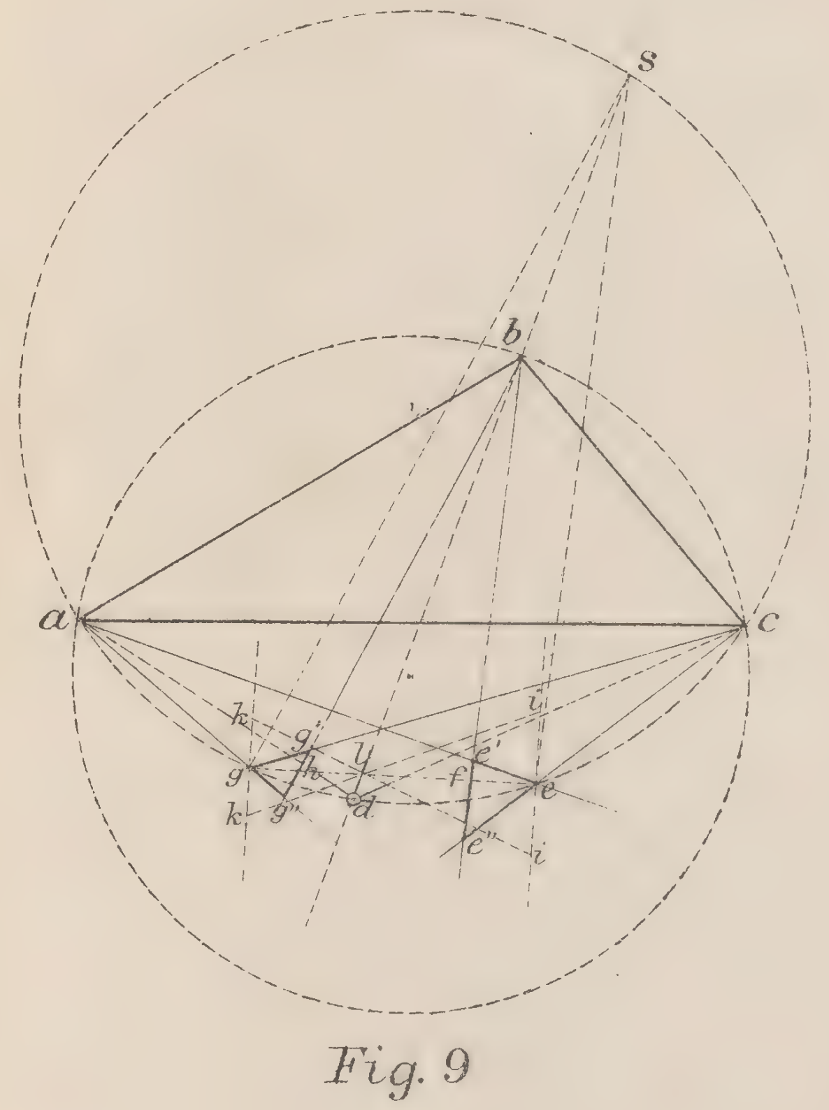

Fig. 9

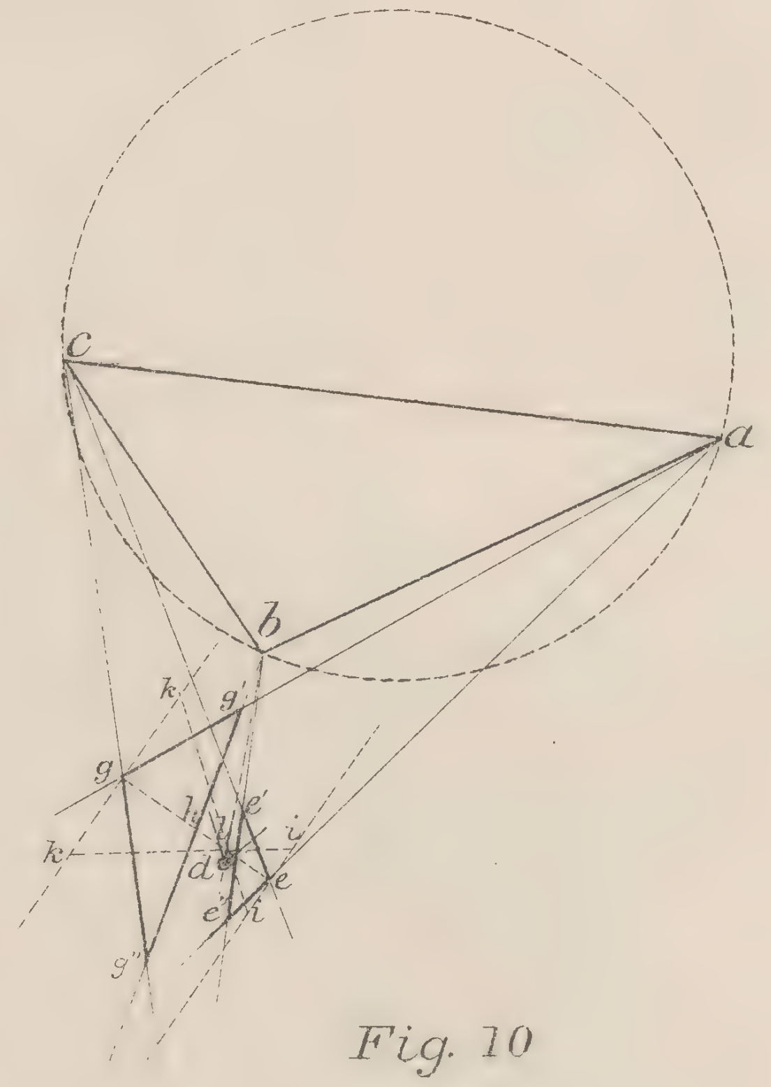

Fig. 10

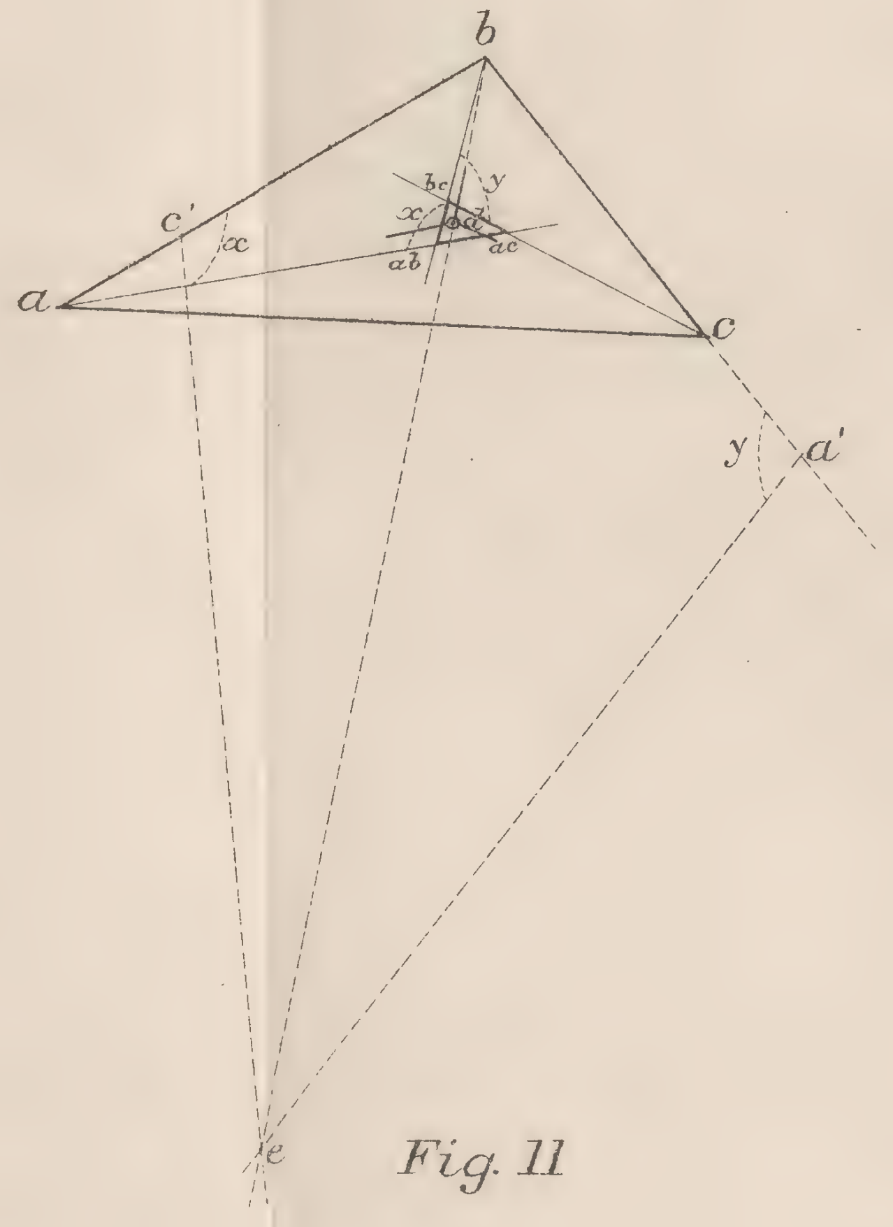
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Fig. 11

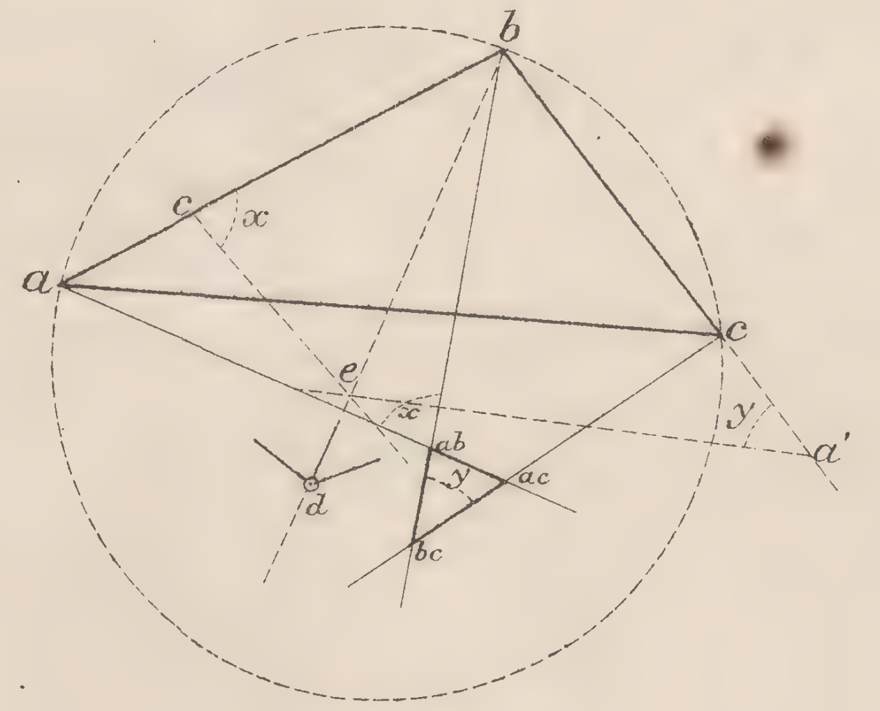
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Fig. 12

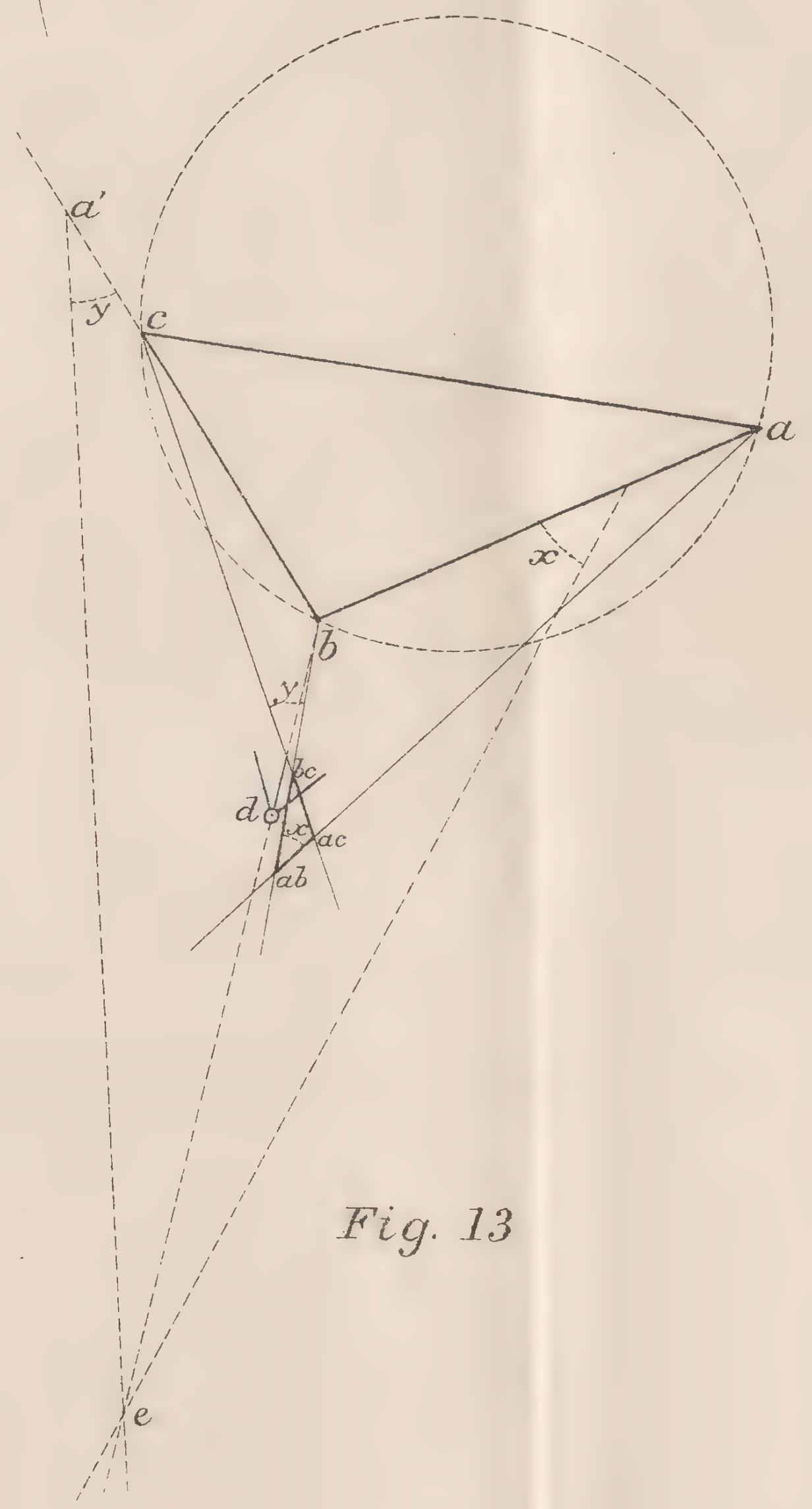
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Fig. 13

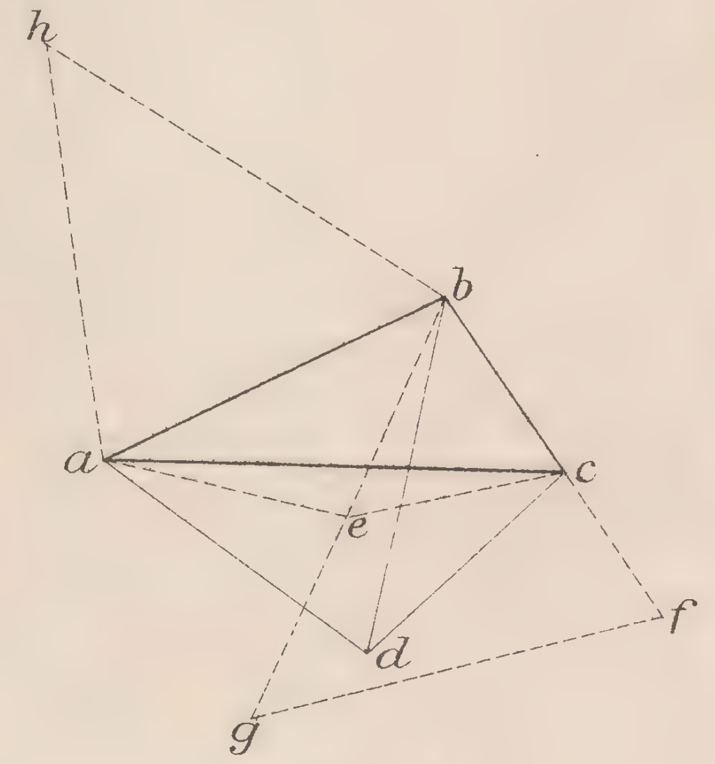

Fig. 14

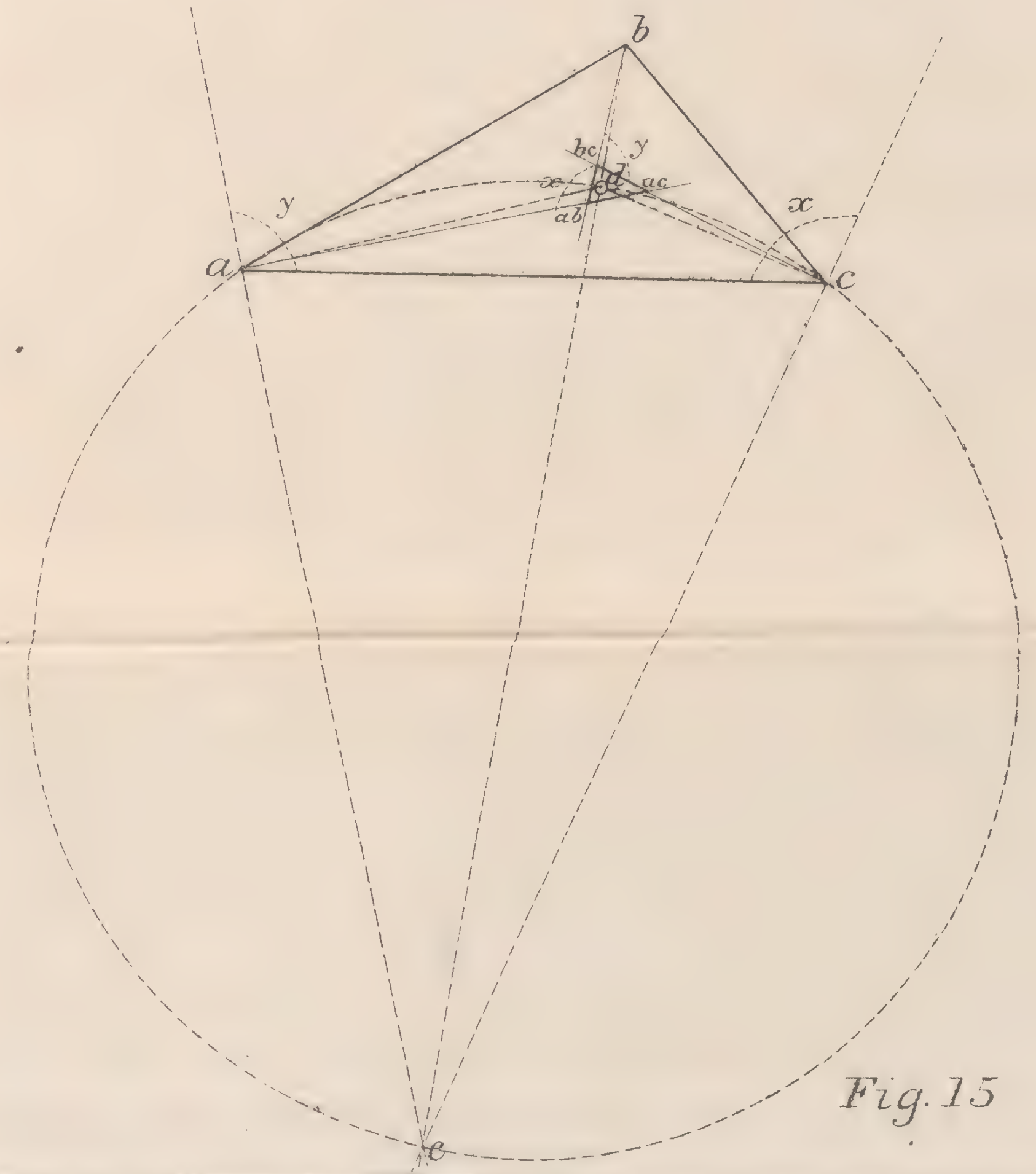
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Fig. 15

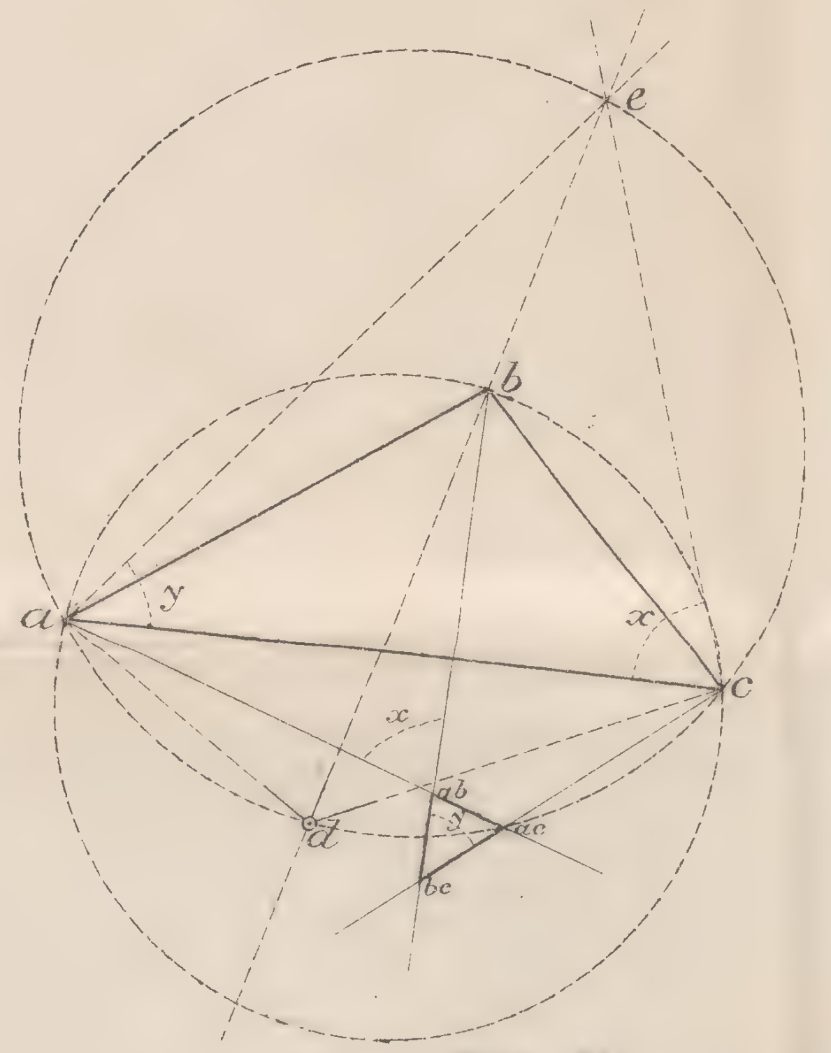
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Fig. 16

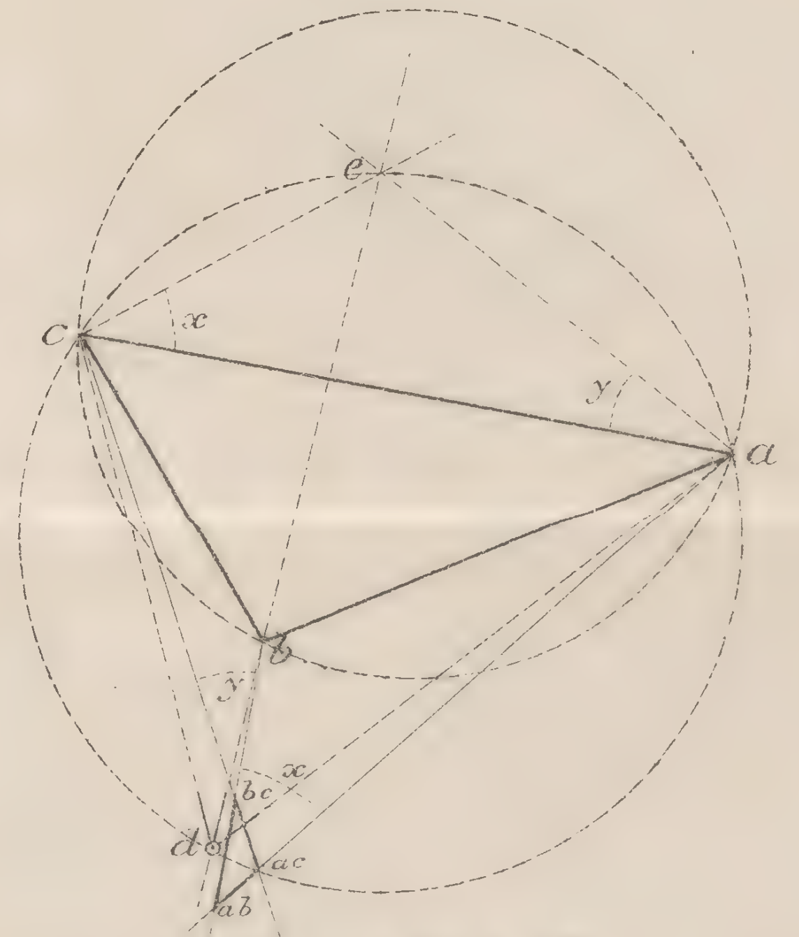
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Fig. 17

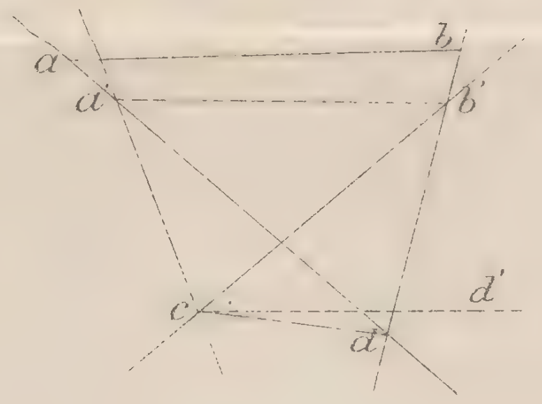


Fig. 18

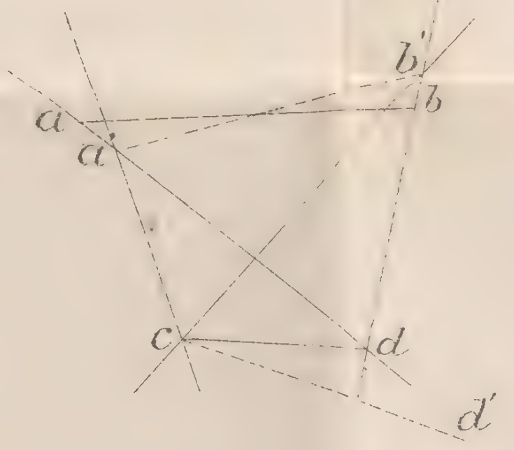


Fig. 19

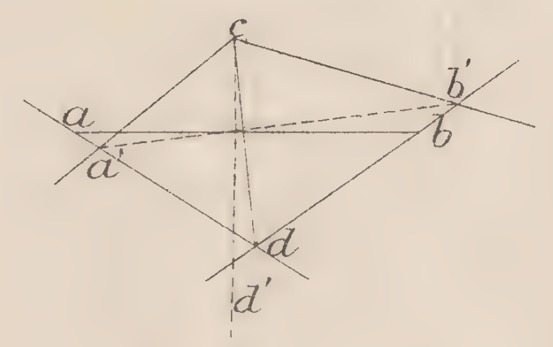


Fig. 20

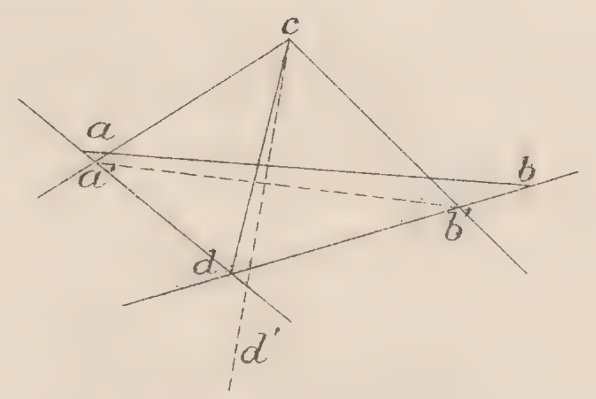


Fig. 21

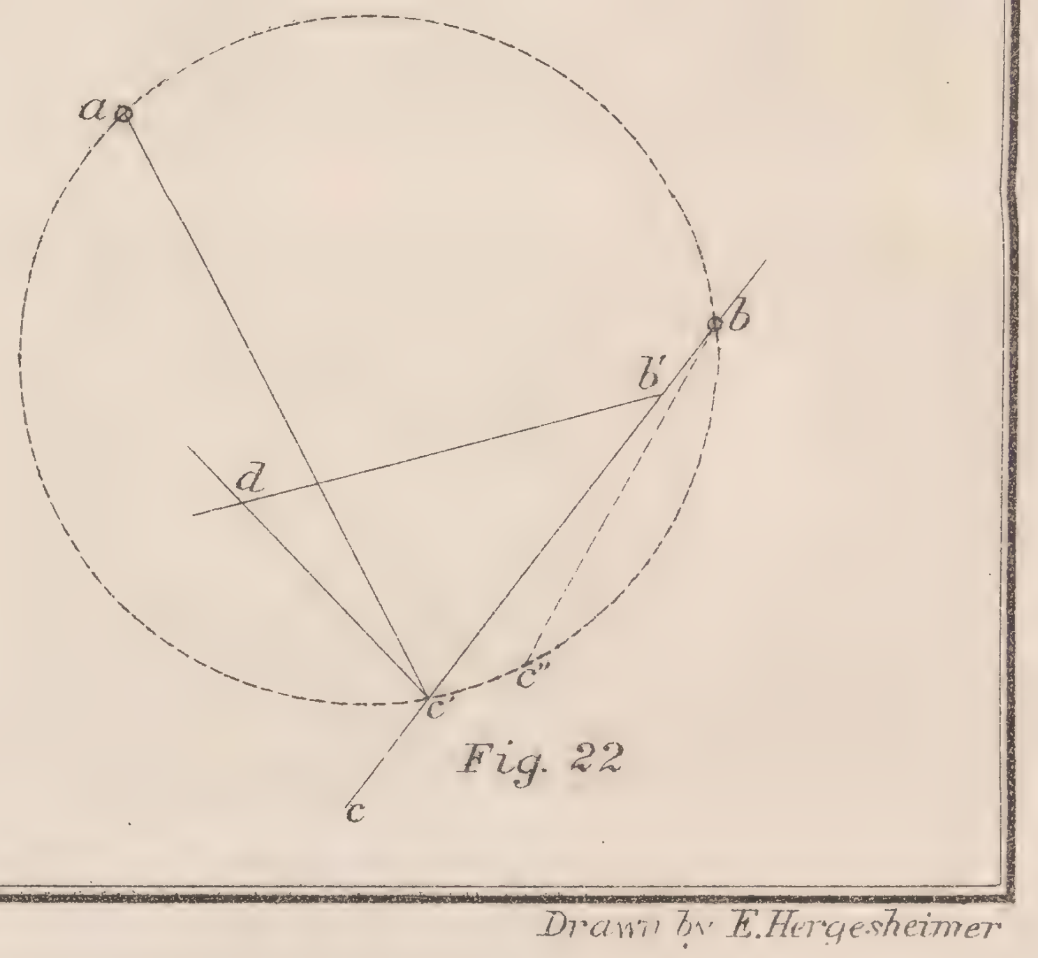
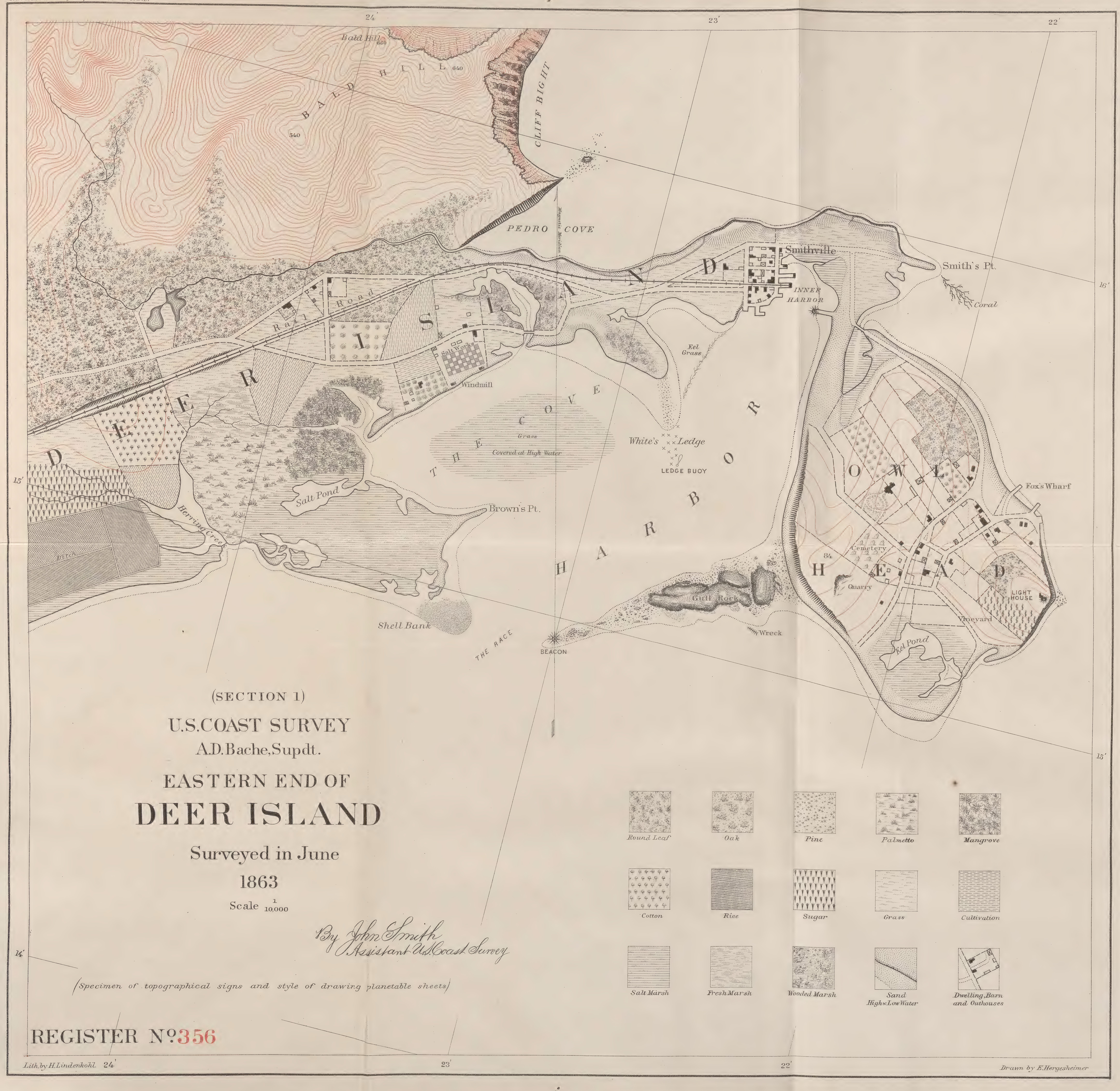


Fig. 22

Lith. by H. Lindenkohl

Drawn by E. Hergesheimer


24'
23'
22'
16'
15'
15'
14'
Bald Hill 660
BALD HILL 640
BALD
340
CLIFF BIGHT
PEDRO COVE
Magnetic Meridian
Smithville
INNER HARBOR
Smith's Pt.
Coral
Rail Road
Salt Works
Windmill
DEER ISLAND
Eel Grass
THE COVE
Grass
Covered at High Water
White's Ledge
LEDGE BUOY
HARBOR
Salt Pond
Brown's Pt.
Herring Creek
Ditch
Shell Bank
THE RACE
BEACON
Gull Rock
Wreck
OWL HEAD
Fox's Wharf
Cemetery
84
Quarry
LIGHT HOUSE
Vineyard
Eel Pond
Round Leaf
Oak
Pine
Palmetto
Mangrove
Cotton
Rice
Sugar
Grass
Cultivation
Salt Marsh
Fresh Marsh
Wooded Marsh
Sand High & Low Water
Dwelling, Barn and Outhouses
24'
23'
22'

(SECTION 1)

U.S. COAST SURVEY

A.D. Bache, Supdt.

EASTERN END OF
DEER ISLAND

Surveyed in June

1863

Scale $\frac{1}{10,000}$

By John Smith
Assistant U.S. Coast Survey

(Specimen of topographical signs and style of drawing planetable sheets)

REGISTER No. 356

Lith. by H. Lindenkohl.

Drawn by E. Hergesheimer

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PROVIDENCE JOURNAL.

TUESDAY MORNING, NOV. 30, 1869.

The Journal To-day Comprises Six Pages.

THE METRICAL SYSTEM OF FRANCE

BY A. M. HARRISON, U. S. COAST SURVEY.

It is not intended in this article to give a detailed account of the history of metrology. The subject is one which would, if fully treated, fill many papers far more voluminous than can here be afforded; but it i thought that to those who have paid the matter but litte' if any, ser ious attention, and who are perhapss ultimately to be in daily use of them, a brief statement of the nature of the measures which they are to employ will prove of some interest.

As the whole subject is now receiving so much elucidation in consequence of the legalization and gradual introduction of the French metrical system into the various branches of trade, commerce and scientific professions of the United States, the few words which are here given to it are purposely merely elementary, and designed only to serve as general information for those who may be interested in the subject.

All measures of whatever kind are composed of sums or fractions of some unit of standard value, and upon the fixedness and accuracy of this element the values of those referable to it depend, and to secure uniformity, simplicity and the least possible variability in this standard, is a problem which has taxed scienfic ingenuity for a long series of years, and upon hich a vast amount of research and refinement of nethods have been expended. As far back as the history of measurements leads us, we find that they had eir origin in the lengths or widths of portions of the man body,—and among those of different countries e found such arbitrary standards as the finger's length and breadth,—the digit, or second joint of the forefinger, the nail, palm, span, cubit or length of forearm, *orgia* or stretch of arms, foot, pace, hairbreadth, etc., etc.

Some of these designations, as the English foot, and the French *pouce*, or thumb, for the inch, are yet in use, and the Arabs are still said to employ the forearm as heir cubit measure of cloth.

The inadequacy of such uncertain and unstable primary lengths to convey definite and accurate notions of measures derived from or founded upon them, was felt at an early day in the perplexing hindrance to commercial intercourse, in their application to itinerary measures, or in the estimation of their extended distances, where a want of agreement in fundamental lengths, which may have been unimportant when but few were considered, would, in repeated multiplication, result in very great discrepancies. These differences, in the progress of mankind toward exactness, led, among the Greeks and Romans, to the establishment of a conventional average of the measurements of different nations;—but even this, though an amelioration, did not satisfactorily remedy the trouble.

Various methods were essayed for arriving at a satisfactory result; but for a long period, even down to a , with but partial success.

In 1324, the statute of Edward II. of England, provides that the length of three round and dry "barley corns" should make an inch, and 12 inches the foot, and so on; but it is apparent that this unit was but little more definite or less crude and irregular than the adoption of the foot of Louis XIV. in France.

Repeated changes of the elemental unit among the different nations of Europe, however, continued to result in unavoidable confusion in the comparisons of their different measurements, and the attempts to overcome these difficulties brought about the institution of careful and accurate comparisons of each given kind of standard in a country, to ascertain which most accuely maintained the measure originally adopted, and select one which should be reliable and which could multiplied and perpetuated.

Accordingly, in 1736, under the auspices of the Royal Society of England, a comparison of the English, French and old Roman standards was made.

Until about forty years ago the standards of weight and measure in England were most irregular.

The standard length was a metal *yard*, which had been in the custody of the Clerk of the House of Commons since 1760. But many of these irregularities were removed by an act of Parliament passed in 1824.

The old yard, by this enactment, is retained as the standard of length, and in order to verify it in case of destruction a ratio was established between its length and the length of a pendulum under prescribed conditions.

It was found that a pendulum vibrating seconds in the latitude of London measured 39.1393 of such inches as are marked on this standard yard, and the standard yard of England is defined by act of Parliament, as "that distance between the centres of the two points in gold studs in the straight brass rod now in the custody of the Clerk of the House of Commons; wherever the words and figures 'standard yard 1760' are engraved, which is declared to be the genuine standard of the measure of length called a yard." As the oscillations, however, vary in different latitudes, and the lengths of the rods are affected by the expansibility of the metal under the changes of temperature—the yard, after all, is at best an arbitrary unit of the measure, and it still remained for some body of scientific men to endeavor to establish or ascertain, from among the fixed objects of nature, a standard clearly definite and unvarying from any cause or combination of causes, and accessible to all mankind, and which, with the most refined application of scientific laws, could be made to serve this most useful and long-needed purpose.

To the French savans of the period of the revolution belongs the credit of measurably effecting this object, and of establishing a metrical system as nearly perfect as the present state of science and human ingenuity and minuteness of investigation can furnish.

The distance in a terrestrial arc between the equator and the pole is a constant quantity, and any assigned part of that distance invariable, and affords an unalterable reference for measures adapted to all purposes of exact metrology.

Upon the measurement of this quadrant of a meridian, the French system is founded, and by a decree of the National Assembly the *metre*, or an aliquot part of the terrestral meridian, the unit of length, capacity, or weight, should be the *ten millionth part of this quadrant*, and the sub-divisions and multiples in the system follow in decimal progression, the sub-divisions of linear measure being designated by the Latin decimal prefixes, *deci*=1-10; *centi*=1-100; *milli*=1-1000; and the multiples by the Greek decimal prefixes of *hecto*=100; *kilo*=1,000; *myria*=10,000. It follows, therefore, that the earth, supposing it to be spherical, is forty millions of metres in circumference, and has a radius of 6,366,198 metres, or, for most practical geodetic purposes, allowing for want of sphericity, the mean radius may be taken at 6,375,110 metres.

M. M. Delambre and Mechain, two distinguished mathematicians, commenced in 1792 the great trigonometrical measurement of an arc of the meridian extending from Dunkirk, in France, to Barcelona in Spain, and completed their work in ——. In 1806, the triangulation was extended from Barcelona through Spain to the coast of the Mediterranean, and subsequently, after the death of Mechain, who fell a victim to his exertions, by Biot and Arago to the Balearic Isles. The whole, thus extended from Dunkirk on the north, to Formentara on the south, comprehends 12° 22′. Cassin and Lacaille had previously measured a smaller arc in 1739; but it is from the former that the standard of the metre, as at present used, is taken.

Before the completion of this measurement, however, it was deemed necessary to employ a "provisional metre," corresponding with surveys already made, and introduced in 1795.

It was not till the 19th Frimaire year VIII (10th Dec. 1799,) that the *legal metre* of France was established. It was ordained that it should be fixed at 443,296 l of the toise of Peru in iron, at 13° Reaumur, or centigrades of the mercurial thermometer, or 32° Fa renheit, the temperature of melting ice. An aversio however, on the part of the French people to th new innovation, as it was considered, induced 1812, the ingrafting upon the metrical system of binary or *systeme usuel*, a species of compromis adopting the new standards; but the divisions corresponding nearly with those heretofore employed, risi generally in ratios of 2, 3, 8, or 12.

This method was abolished in 1837, however, and after a struggle, which had already been protracted through a series of years, against old prejudices and habits, and various political and commercial obstacles, the establishment of the metre and its derivatives was finally adopted, in France in 1840, to take effect after the 1st of January. Since that period the system has rapidly advanced in favor, not only in that country, but among scientific men of all other nations, and its use is now authorized by act of Congress in the United States.

Thus one common unit, based on a subdivision of the earth's surface, furnishes a key to the size and capacity of all the metrical weights and measures; bu this fact would not prove a very good reason for th proposed change, were it not accompanied by a syste by which each of the units mentioned above is divide decimally, and larger units formed by multiples ten, one hundred, &c.

It has already been ascertained that the measurement of the meridian, on which the metre is founded is, by a minute fraction, too small; in other words, th the whole circumference determined is slightly *over* 40 000,000 metres in length. According to Bessel, the dis tance from the equator to the pole, thus established, 935 yards too small, according to Puissant, 1,410, an according to Chazallon, 1,967. The metre is not the strictly speaking, the ten millionth part of the quart of a meredian, but the difference is so minute as not be appreciable in ordinary geodetic work; but from th fact that the artificial standard cannot, without a lab which ran through a course of years, and which coul hardly be expected would be again undertaken, be co rected by a recurrence to the standard in nature, th metre itself becomes in fact no less arbitrary than th yard or foot.

Its chief value rests, therefore, upon the beautif and simple system which is founded upon it, and upo that chiefly does its claim to superiority rest. Th metre is marked by two very fine parallel lines drawn on a bar of platinum and preserved in the archives of the Academy of Science in Paris.

In a scientific point of view no system of metrology hitherto devised can compare with this of the French, and the following gives the multiple and divisions as established:

Myriametre	10,000.	metres.
Kilometre	1,000.	do
Hectometre	100.	do
Metre	1.	do
Decimetre	0.1	do
Centimetre	0.01	do
Millimetre	0.001	do

And the following gives these values in standard Eng lish inches, the metre being taken at 32°, and the foo at 62°:

Millimetre	.03[illegible]
Centimetre	.3[illegible]
Decimetre	3,937[illegible]
METRE	39.37[illegible]
Decametre	393.71000
Hectometre	3937.10000
Kilometre	39371.0000
Myriametre	393710.0000

This represents Kater's value; Baily more relia gives 39.37009 as the value of the metre in inches, the standard of the Coast Survey, which was suppos to be identical with those used in the above compa sons gives 39.36850. These differences are mainl questions of the expansion by temperature of particul pieces of metal, since you cannot well compare a me at 32° with a yard at 62°; 39.3700 inches is as near h

ever as under the present stage of unformation it is worth while to go,—1-10,000 of an inch is an exceedingly small quantity. In all horizontal measurements in the United States Coast Survey the French metre is employed, and in the calculation of heights the English foot is used. Appended are tables which may at times be found serviceable for reducing metres to feet, yards, and rods and *vice versa,* also the values in metres of the English nautical and statute miles.

With regard to the relation of the yard to the metre, a very convenient set of factors, easily remembered, and quite accruate when ordinary variations of temperature are thrown in, is 1 yard=4x8—5x7 metres:

TABLE FOR REDUCING METRES TO FEET, YARDS AND RODS.

Metres.	*Feet.*	*Yards.*	*Rods.*
1....	3.281....	1.094....	0.199
2....	6.561....	2.187....	0.398
3....	9.842....	3.281....	0.596
4....	13.123....	4.374....	0.795
5....	16.403....	5.468....	0.994
10....	32.807....	10.936....	1.988
20....	65.614....	21.871....	3.977
40....	131.228....	43.743....	7.953
50....	164.035....	54.678....	9.942
100....	328.071....	109.357....	19.883
500....	1,640.354....	546.785....	99.415
1000....	3,280.709....	1,093.570....	198.831

FOR REDUCING FEET, YARDS AND RODS TO METRES.

Feet.	*Metres.*	*Yards.*	*Metres.*	*Rods.*	*Metres.*
1....	0.305....	1....	0.914....	1....	5.029
2....	0.610....	2....	1.829....	2....	10.059
3....	0.914....	3....	2.743....	3....	15.088
4 ...	1.219....	4....	3.658....	4....	20.118
5....	1.524....	5....	4.572....	5....	25.147
10....	3.048....	10....	9.144....	10....	50.294
20....	6.096....	20....	18.289....	20....	100.588
40....	12.192....	40....	36.577....	40....	201.176
50....	15.241....	50....	45,722 ...	50....	251.470
100....	30,481....	100....	91.444....	100....	502.940
500....	152.406....	500....	457.218....	500....	2,514 700
1000....	304.812....	1000....	914.437....	1000....	5,029.400

1 Nautical mile..............................1855.110 metres.
1 Statute mile..............................1609.408 do

We have thus given a few notes on *lineal* measure only. The development of the metrical system into the corelative branches of measures of capacity, weights and coinage, which are founded upon it, may, if this article prove acceptable, be treated upon in another paper.

Projection Tables

from

Coast Survey Reports.

APPENDIX No. 39.

*Tables for projecting maps, with notes on map projections.**

MAP PROJECTIONS CLASSIFIED AND DEFINED.

That department of descriptive geometry, or analysis, which treats of map and chart projections, has to deal solely with the terrestrial spheroid, and especially with the representation of the parallels and meridians subdividing its surface. As all localities, both on land and sea, are most readily and generally determined by latitude and longitude observations, so it is the most available and universal method, in constructing maps, to refer all positions to meridians and parallels as co-ordinate lines.

If we conceive the earth's surface reticulated by a complete framework of parallels and meridians, it is then the specific and uniform object of all modes of projection to represent these lines on a plane surface, in the most advantageous manner. But, as the spheroid is incapable of direct development on a plane, it only remains to present, in projection, the *best* approximation to similitude in form, relation, and proportional area in the parts of the earth's surface to be represented.

Ptolemy, Lambert, Euler, Lagrange, De L'Isle, Monge, La Croix, Puissant, Henry, Gauss, and others, have treated of projections in more or less detail, and some of them by methods of the highest grasp and compass.† This general problem has led to the following modes of projections, (all technically, though some quite incorrectly so called,) each of which has been used, and most of which possess advantages for some descriptions of maps or charts. This classified synopsis will serve to show more precisely the relative value and precise character of the polyconic projection.

CLASS I.—Perspective projections on planes.......	Orthographic.
	Globular, or equidistant.
	Stereographic.
	Gnomonic, or central.
CLASS II.—Developed perspective projections.....	By a tangent cylinder.
	By a secant cylinder.
	By a tangent cone.
	By a secant cone.
CLASS III.—Projections by developing elements....	Cassini's.
	Flamstead's.
	Bonne's, or the modified Flamstead's.
	Polyconic, (U S. Coast Survey.)
CLASS IV.—Projections conformed to some arbitrary condition........................	The flat chart, with equal latitude degrees.
	The flat chart, with latitudes = radius × sine of latitude.
	De Lorgna's.
	Ptolemy's modified conic.
	Mercator's.

CLASS I.

All simple perspective projections are made by supposing the eye at some particular point, and the plane of projection or representation to be pierced by all the rays, or rays prolonged, between the eye and all points of the parallels and meridians. The curves composed of all these piercing points of rays constitute a perspective projection. A projection is practicable for any possible position of the eye or plane, (except when the eye is in the plane,) but only a few among this infinite number of perspectives are convenient or eligible for construction.

In the *orthographic* projection the eye is assumed at an infinite distance, and the projecting rays are parallel lines to which the plane of projection is perpendicular at any point desired. By this method circles are projected into ellipses, and the outer parts of the projected hemisphere are very much crowded.

---

* The notes on projections were prepared by Lieutenant E. B. Hunt, U. S. Engineers, and the formulæ and tables were arranged by Mr. Charles A. Schott, of the Computing Division.

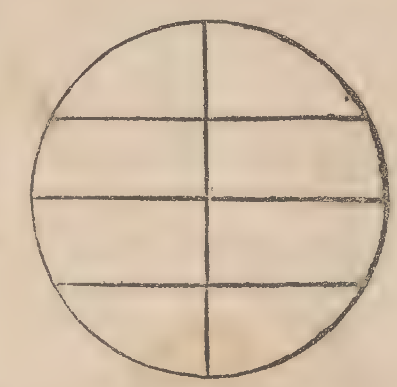
† Reference on this subject may be made with advantage to the following general treatises: Puissant, "Traité de Topographie," 1805; Henry, "Memoire sur la projection des Cartes," 1810; "Memorial du Depot de la Guerre," Tome II and IV: La Croix, "Precis Astronomique," in "Pinkerton's Geography;" Barbie, Dubocage, and La Croix, vol. I, "Memorial Topographique et Militaire," Francoeur's "Traite de Geodesie;" Gehler, "Physickalisches Worterbuch;" Mayer's "Practical Geometry," 1828; "Littrow's Astronomy," 1812; Narren's "Astronomy and Geodesy," 1845; Jackson's "Chartography," in "Manual of Geographical Science," 1852.

TELESCOPIC MEASUREMENT IN SURVEYING.

BY BENJAMIN SMITH LYMAN, MINING ENGINEER,

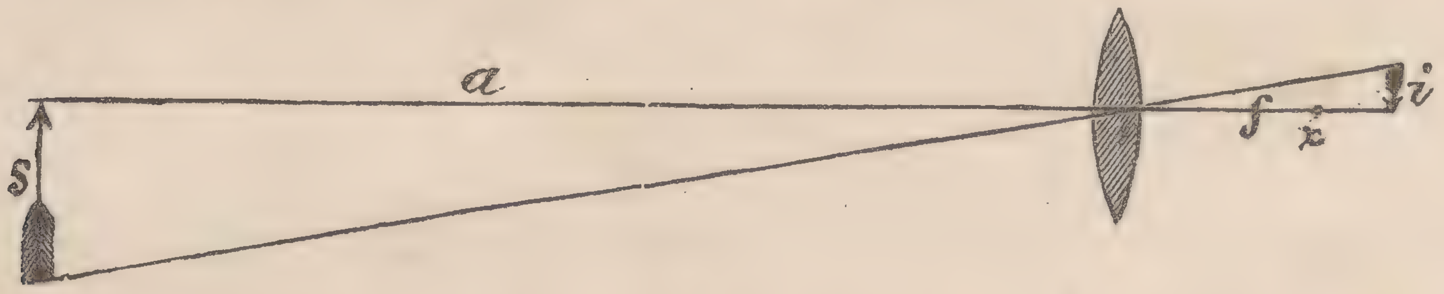
135 *South Fifth Street, Philadelphia.*

Read before the Franklin Institute, at the Stated Meeting, March 18th, 1868.

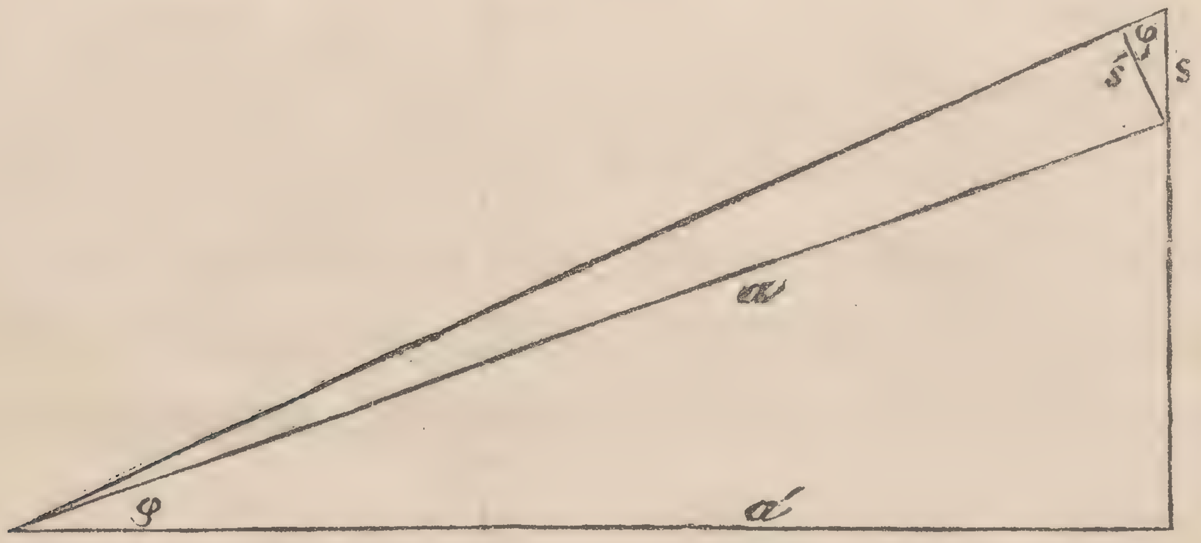


FOR measuring distances with the telescope, in surveying, the telescope has two or more horizontal cross-hairs besides the ordinary vertical one. In sighting at an upright rod, these horizontal cross-hairs cut off a portion of the rod that is larger or smaller according to the distance of the rod; five times as much, for example, for a distance of a thousand feet, as for one of two hundred feet. A rod graduated to indicate distances in this way, with the help of the telescope, is called a *stadia* by the French, and has been in use some fifty years. In the United States Coast Survey such a rod is called a *telemeter*. The object of this paper is to show that such telescopic measurements in their simplest form are more exact than is perhaps commonly supposed even by professional surveyors; as well as to point out some improvements in the details of the apparatus that add very much to its convenience.

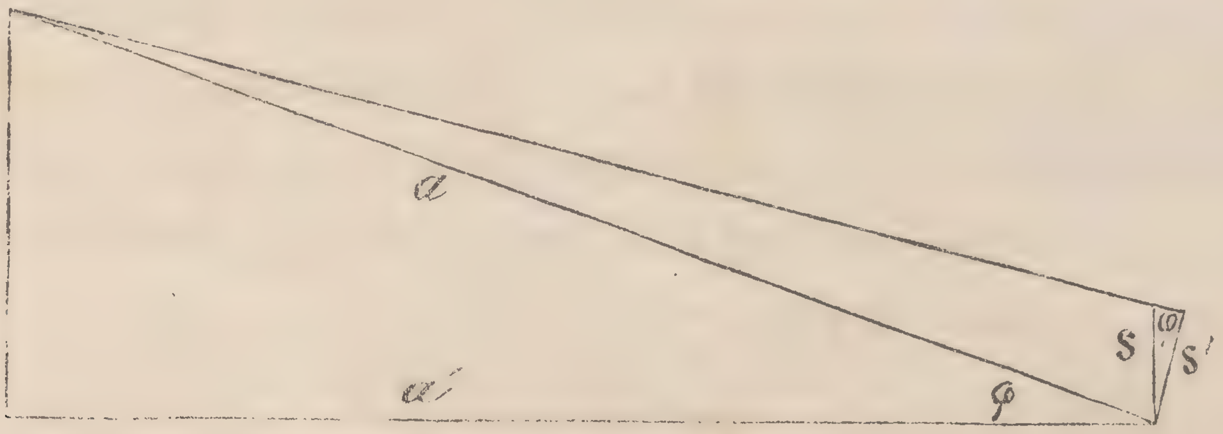
De Sénarmont, nineteen years ago, in the *Annales des Mines* (Fourth Series, vol. xvi.), in a notice of some improved apparatus for telescopic measuring, by Mr. Porro, a Piedmontese, speaks of the stadia as having been used hitherto for rapid and approximate surveys; and gives briefly the theory of its use. If the size of the object seen through the telescope be called s; the distance from the object to the centre of the objective a; the size of the conjugate image of the object, equal to the distance apart of the two horizontal cross hairs, i; the distance of this image from the centre of the objective x; and the focal length of the objective f: then, $\frac{a}{x}=\frac{s}{i}$. But the general formula of foci of lenses gives $\frac{a}{x} = 1 - \frac{a}{f}$. Therefore, $a - f = \frac{f}{i}s$; or $a = \frac{f}{i}s + f$. Practically the distance a has commonly been reckoned so large that the small distance f was neglected, and the formula became $a = \frac{f}{i}s$; in which $\frac{f}{i}$ is a numerical coefficient peculiar to the instrument, and determined by observation once for all. The distances, in that case, are reckoned proportional to the space cut off on the rod, counting from the centre of the instrument, whereas they ought strictly to be counted from a point as far in front of the objective glass as the focal length of that lens.



In case the telescope in measuring is not level, it is necessary to make besides a double correction; because, in the first place, the space cut off on the vertical rod is greater than if the telescope was sighted level; and, in the next place, the corrected distance of the rod in the slanting direction must be corrected again to give the distance reduced to a level. For if s be the space cut off on the rod viewed slantingly, and s' the corresponding space when the rod is held square with the line of sight; if a be the distance of the rod from the telescope in the slanting direction, and a' the correct horizontal distance; and φ the angle of the slant with the horizon: then

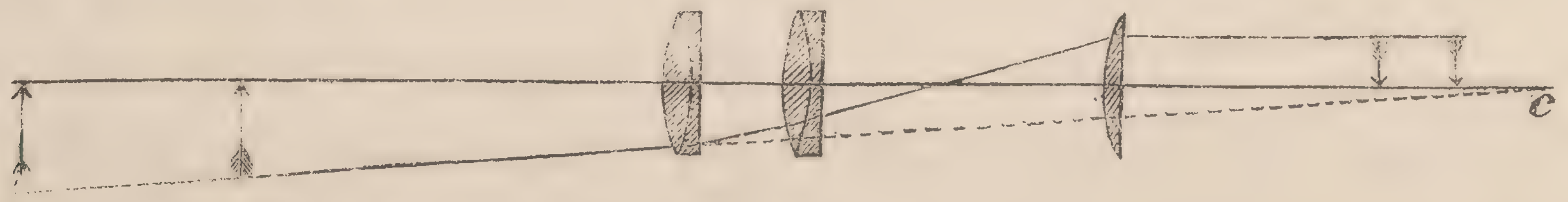


$a' = a \cos \varphi$; $s' = s \cos \phi$; $a = n s'$, where n is the numerical coefficient $\frac{f}{i}$ peculiar to the instrument; and $a' = a \cos \phi = n s' \cos \phi = n s \cos^2 \phi$. It is necessary, then, to multiply the distance indicated by the rod by the square of the cosine of the angle of the sight with the horizon. If, however, account be taken of the necessity, for exactness, of counting the distance a from a point as far in front of the object glass as the focal length (f) of that lens; and also account of the distance of that lens in front of the axis of the instrument, say d; then, $a' = (a + f + d) \cos \phi = n s \cos^2 \phi + (f + d) \cos \phi$. But $(f + d)$ is so small a distance, that with the angles common in practice it differs but a trifle from $(f + d) \cos \phi$, and may be reckoned as the same thing; so that, then, $a' = n s \cos^2 \phi + (f + d)$. The quantity $(f + d)$, then, is a small constant, easily determined for each instrument, say one foot or two, that must be added to each level measurement, and to each corrected slanting measurement. Sometimes, when the telescope is not level, the rod is leaned over so as to be square with it; but this is less convenient than the way of correcting just described, for the correction for the slope of the ground has to be made at any rate, and it is extremely easy to make the other at the same time.



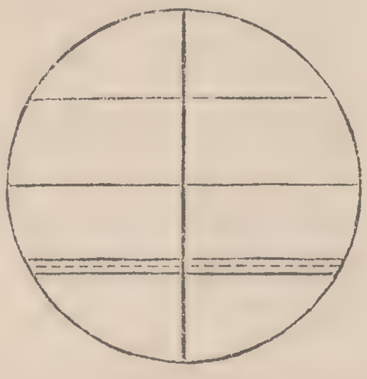
De Sénarmont remarks that experince shows that it is possible to subdivide by guess to a tenth a space that subtends an angle of about sixteen minutes. If, then, the rod when magnified by the telescope subtends an angle of about ten degrees, its length could be marked off in forty divisions, and each of them be subdivided by the eye within a tenth. If, for example, the telescope magnified ten or twelve times, like the ordinary ones on transits, for a range of say 660 feet (ten chains or a furlong), then the rod might be something over thirteen feet long, and be marked with divisions a third of a foot long, and then could be subdivided by the eye within a thirtieth of a foot. This limit of exactness would correspond to a foot and two-thirds of distance on the ground, or $\frac{1}{400}$ of the furlong. But if the telescope magnified twenty times, like the telescopes of levels, the divisions on the same rod could be twice as small, so that the limit of error in the reading of the rod would be twice as small also; and the error in the distance on the ground, therefore, would be not more than five-sixths of a foot, or $\frac{1}{800}$ of the whole distance. This, however, is about the greatest exactness that can be obtained in this way with ordinary glasses; since in this case the magnified rod extends about ten degrees in either direction from the focal axis, and more than that the eye-glass cannot embrace without aberrations that are quite too great; so that, if the power of the telescope be increased, the length of the rod and of its divisions must be diminished in proportion.

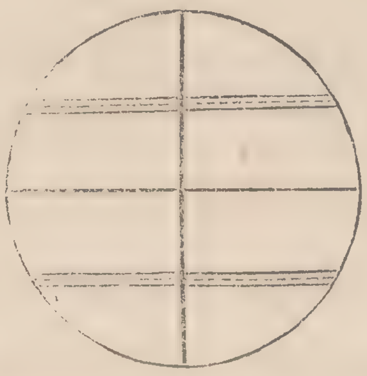
Mr. Porro's improvements, then, aim at an increase of the field, and at the same time of the power; and, besides, the distances are made to count from the axis of the instrument. This last change is effected by placing between the focus of the objective and the cross-hairs an additional lens whose focus is at the same point as the focus of the objective. The rays, then, after passing the added lens are parallel, and all objects that subtend the same angle from a certain point (*c*) behind the objective (a point which he calls the centre of "anallatisme," that is, of unchangeableness, and whose position is determined by the refraction and distances of the lenses) would have images of the same size, and the size of the objects would be proportional to their distance from that centre. The cross-hairs would, then, cut off a space on the rod proportional to the distance of the rod from the centre of unchangeableness, and this centre may be placed at the axis of the instrument; so that the distances found by reading the rod would be counted immediately from that axis, and if they were not level would be corrected, to get the level distance, simply by multiplying by the cosine square of the angle above or below level.

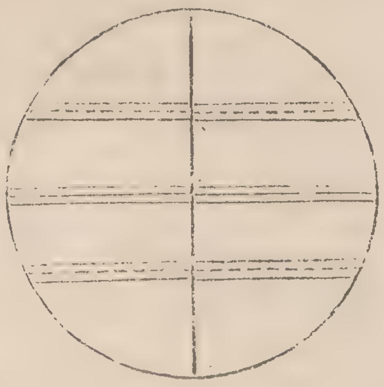


Then, in order to increase the available extent of the field, Mr. Porro used three eye-glasses, which observed the upper, middle and lower parts of the image; so that the cross-hairs could be put farther apart, and by having an eye-glass opposite each one no error would come from the spherical aberration. But, in order to have a sharp and bright image for these eye-glasses to observe, and yet not need a large objective (which would require a focal length at least twelve times as long as the diameter of the lens to avoid excessive spherical aberration), he used two separate achromatic objectives placed one behind the other, that is, a compound lens, such as had long been used for achromatic microscopes and for cameras. By these means he made telescopes of two inches and a third across and only about fifteen inches in focal length, with a magnifying power of sixty or eighty times; and with the triple eye-piece they enabled him to read distances within at least $\frac{1}{2000}$, and so reduced the uncertainty to less than a third of a foot in 660 feet.

More than that, instead of using simply two horizontal cross-hairs, one above and one below, with or without the middle cross-hair, he always replaced the lower cross-hair by two, at one-tenth the distance from each other that the replaced hair would have been from the upper one, making three cross-hairs besides the middle one. Sometimes also he replaced the upper in like manner by two, making five, counting the middle one; and sometimes he placed two more just above and below the middle, making seven cross-hairs in all. These additional cross-hairs serve to show that there has been no material error in the reading, and that the divisions of the rod have been correctly subdivided by the eye, and that the sighting is correct when certain divisions are not distinctly visible owing to obstructions. He obtained in this way, with a magnifying power of sixty or eighty times, and with five cross-hairs, and with the divisions of the rod $\frac{13}{100}$ of a foot (four centimètres) long, an exactness within less than $\frac{1}{2000}$ up to a distance of a furlong; between a furlong and a quarter of a mile the middle cross-hair and two outermost ones, gave an exactness of a good deal less than $\frac{1}{1000}$; and between a quarter of a mile and half a mile, one of the outer pairs of cross-hairs, gave an exactness within $\frac{1}{400}$.







De Sénarmont remarks that such a telescope may be advantageously adapted to geodesical, leveling, topographical or land-surveying instruments; but that, applied to the ordinary compass, to the alidade of the plane table, or to the graphomètre, it would give even with a reduced magnifying power a greater exactness than could be obtained with these instruments for the other elements of a topographical projection; and so some of its advantages would be wasted. He admits, also, that the instrument requires extremely nice workmanship, such as few instrument-makers are capable of; and, although it is possible to test the correctness of the different parts, there appears to be no way of adjusting the position of the cross-hairs without removing them from the telescope.

If, however, the number of horizontal cross-hairs be restricted to three, one above and one below the middle one, they can all easily be made adjustable by screws on the outside of the telescope, if the upper and lower hair be placed a very slight distance before or behind the vertical hair, a distance that can give rise to no incovenience. Observations with the two upper and two lower of the three cross-hairs, (that is, with all three at once) check each other, and if too little of the rod be visible for that, then two successive observations on different parts of the rod, with either one or both pairs, serve the same purpose. In these ways the lack of Porro's additional cross-hairs is very conveniently supplied, except in the sights that are more than a quarter of a mile long. These extremely rare sights, where even his apparatus claims only the indifferent exactness of $\frac{1}{400}$, it is necessary to give up, and make instead two shorter sights with more exact results.

A convenient way of marking the rod with very small divisions removes the fatiguing necessity of subdividing the divisions by the eye to a tenth, and enables the use of a much weaker telescope. According to Plateau, a red disk lighted by sunlight merely reflected by the clouds can be seen distinctly at a distance equal to 6000 times its diameter; according to Müller, at a still greater distance, especially with a favorable background; but with a telescope magnifying twenty times this distance of distinct visibility, becomes 120,000 times the diameter of the disk. It has already been seen that with a simple telescope of that power, the rod can be at most something over thirteen feet long for a range of a furlong; that is, the length of the rod may be one-fiftieth of the length of range. The smallest visible mark on this rod at the distance of a furlong would be not more than $\frac{1}{120000}$ of 660 feet, say $\frac{1}{182}$ of a foot long. A cross-hair, wherever it should cut a rod divided throughout with such marks, would be within one-half the length of a mark from the centre of one of them, or within $\frac{1}{364}$ of a foot of the reading; and this would correspond to a distance of $\frac{50}{364}$ (less than a seventh) of a foot on the ground. This, then, would be the exactness with such a telescope and such a rod, $\frac{50}{364}$ of a foot in 660 feet, or $\frac{1}{4800}$; and for distances between a furlong and a quarter of a mile the exactness would be within $\frac{1}{2400}$. That is more than twice as exact as Porro's large and complicated instrument with his rod less finely divided; and yet requires no larger field than can be got with a common telescope that magnifies twenty times and has but a single eye piece. A magnifying power of ten times with a rod of the same length would give one-half the degree of exactness at those distances; and the marks on the rod must be twice as large, say, $\frac{1}{100}$ of a foot long. At a distance less than a furlong a smaller space on the rod could be distinguished, but it would be the same fraction of the distance measured, so that the exactness would be no greater.

Such small divisions are readily marked on the rod and made easily legible simply by dividing the feet into tenths, and marking each tenth of a foot with an angular figure, whose angles indicate each a division of one-hundredth of a foot. The rod marked in this way can be used for leveling as well as measuring; and the cross-hairs can be adjusted so that one foot on the rod between the middle and upper or lower cross-hair corresponds to a hundred feet, and the reading gives the distance directly in feet. So adjusted, a telescope that magnifies twenty times uses in measuring just the whole of its available field; but a telescope that magnifies ten times uses only half of it, and is therefore far within the limits set by the spherical aberration of the outer part of the field.

The correction done away with by using the additional lens and reducing the centre of unchangeableness to the axis of the instrument is otherwise made so simply, as already shown, by merely adding to every distance as read from the rod a constant (say, one foot) equal to the focal length of the object glass added to the distance of that glass in front of the axis of the instrument, that the use of those complications seems, on the whole, to have no advantage.

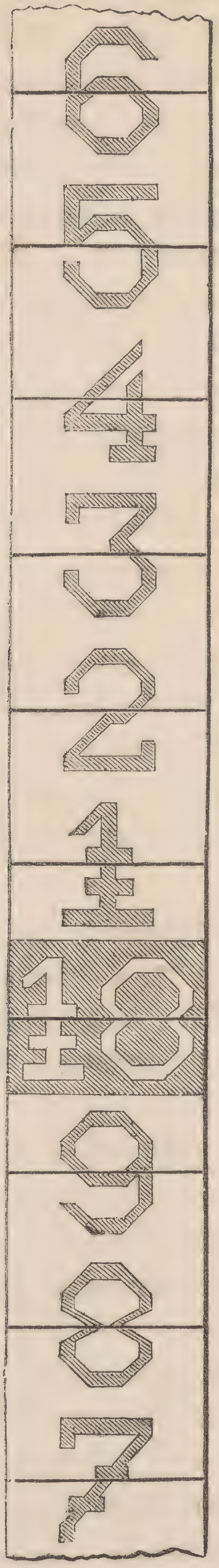
Instead of reading the distance directly on the rod by the telescope, a movable target may be used with a vernier. One cross-hair is sighted at the zero point on the rod, or at a fixed target, and the movable target is moved to correspond with another cross-hair, and the space cut off in this way on the rod is read by the rodman; and if a vernier be used, can easily be read to a thousandth of a foot, if desired. Such a rod was used in the fall of 1862, in a topographical survey in Schuylkill County, with a measuring telescope that magnified about ten times attached to a light compass. There were three horizontal cross-hairs, not adjustable, but fixed, by chance, at such a distance apart that two inches on the rod between the middle cross-hair, and either one of the others corresponded to ten feet of distance on the ground.

The exactness of this measurement was satisfactory, but the moving of the movable target was so tedious, that the next spring a rod was made for similar topographical use, so marked that the distances might be read directly with the same telescope. The numbers of every other division on the rod were indicated by diamond-shaped spots, two-fifths of the division in diameter, and placed on either side of a dividing line, with one point at one-fifth of the division from that line, and the opposite point at twice that distance from the next line; so that the whole of each division was easily divided by the eye into ten parts, by halving the side of a spot or halving, or quartering the space between the spot and a dividing line. The cross-hairs were put nearer together, too, so as to bring them further from the outer edge of the field. It was wished to have them just half as far apart as before; but they proved to be so far apart, that $\frac{36}{35}$ of an inch on the rod corresponded to ten feet of distance, and the rod was divided accordingly. This telescope and rod were used very successfully through the summer and fall of 1863. The first part of the season, the levels were taken by means of angles on a vertical circle, as they had been the year before; but after that, to avoid the uncertainties and excessive office work of that method, an ordinary level-rod was carried, besides the one for measuring, and the level was taken in a separate observation for each station with the help of a spirit-level attached to the telescope of the compass. The running, in such a case, is done with front and back sights, like leveling, with one rod; and, as the sights are level, no correction is needed for slope. The exactness of these methods, even with so slight an instrument as the compass was, and their thorough satisfactoriness in that respect for geological purposes are illustrated by the fact that a shaft was sunk, in 1866, in Cape Breton, at a point where it was calculated by a map constructed, in 1863, from materials obtained in this way, that the bottom of a certain coal-bed, dipping about one in ten, would be 180 feet deep, a point about three-quarters of a mile distant from the nearest exposure of the bed, when the map was made; and the depth proved, in fact, to be 182 feet.

The next winter a new rod was made and divided into feet and tenths of a foot, and marked in the same way as the other had been.

Also, the measuring cross-hairs in the telescope of a new transit, with a magnifying power of about ten times, were made adjustable by screws, so as easily to be placed just so far apart that one foot of space cut off on the rod by two near cross-hairs should indicate a distance of one hundred feet; and the rod could be used at the same time for leveling, as there was a level on the transit telescope. This apparatus was used very successfully through the summer and fall of 1864, and again in the fall of 1865. In measuring important lines, every measurement was checked by a double observation, and every compass-angle roughly checked by reading also the angle of the vernier plate; so that no station was left until it was seen that no important error in reading had been made; a mode of checking that is much better than running over a line a second time. The screws that adjust the measuring cross-hairs are just behind the screws that adjust the middle horizontal cross-hair; and as the upper one was found to be exposed to being struck and turned by the limbs of trees or bushes in carrying the transit through the woods, and so making an error in the measurements before it was discovered, a cap, open on both sides, has been put over the head of this screw, to protect it completely. The telescope of a solar compass was also furnished with one fixed and one adjustable horizontal cross-hair for measuring, and was used successfully in this way with the rod just mentioned.

The same transit was also used in the fall of 1865, with great success, for measuring underground in a coal mine, and it saved much disagreeable groping in the mud to count the links of a chain; and levels were taken at the same time, with one rod. The figures on the rod, in this case, were painted with red ink upon thin paper that had been fastened to strips of common window-glass by transparent varnish, such as photographers use on their negatives. Then another coat of varnish was poured over the paper, and another strip of glass was placed upon that. The glasses, with the paper between them, were then put into a long, narrow frame of pine wood, five-eighths of an inch thick and an inch and a-half wide in the clear, which formed one side of a long box, three inches and a quarter square inside. The box has neither top nor bottom, and its sides are so hinged together that they fold over upon each other when not in use, so as to protect the glass and take up less space. The back of the box has holes through it, to supply air to the lights; and either little mine-lamps, or candles in little tin sockets, are stuck in the wood of the back. This box was made five feet long; but for low mines one might be made much shorter, say, a lantern one or two feet long (perhaps of tin), and for leveling it could have a leg that would slide in or out, so as to raise the lantern to the required height from the ground. The inside of the wooden box may be painted white, to reflect the light well, or be lined with tin, and the outside may be painted black, so as to show less the black dirt of coal mines and the grease and smoke of the lamps.



One-half of full size.

The figures on this underground rod are the common Arabic numerals, made a hundredth of a foot thick throughout and very angular, so that each hundredth of a foot in their height is marked by an angle. Every tenth of a foot is marked with a number, instead of every other division, as on the two other rods. The feet are marked by the same figures, but they are made white on a red ground; and the red ground reaches half a tenth of a foot each way from the foot-mark, so that the feet are very conspicuous at a distance. The rod for use with the transit above ground has now been repainted with these figures, as they are much more convenient for reading. They are cut in a stencil-plate, and are, therefore, easily marked on the rod; it would be still more convenient to stamp them with a die. They are eight hundredths of a foot long, four hundredths above and four below the line, and the fifth is easily estimated by the eye at half-way between one figure and the next. Of course, a land surveyor could have the rod divided into links and portions of a link, and marked accordingly; or he could so adjust the cross-hairs, that a foot on the rod would answer to a chain on the ground.

The rod is, then, in effect, marked with divisions a hundredth of a foot apart, and a telescope that magnifies ten times should, for distances less than a furlong, be exact to $\frac{1}{2400}$, that is, at most, about three inches; and to $\frac{1}{1200}$ for distances between a furlong and a quarter of a mile; and with a telescope twice as powerful, should be about twice as exact, since the smallest divisions could be halved by the eye. The exactness, then, with a telescope that magnifies twenty times, is at least as great as that claimed for Porro's larger instrument. Telescopes that magnify only ten times, with this rod, would measure, on the whole, much more exactly than the chain. Of chaining, Wm. A. Burt writes as follows, in his "Key to the Solar Compass," p. 35.

"Measurements with the chain and tally-pins are often very imperfectly performed by the chain men, and much more error is made than is generally supposed. It has been found by many trials, with as good men as can generally be obtained, that with two sets of chain men, instructed alike in the proper manner of keeping the chain level and straight on the line, and of setting the tally-pins plumb, as well as holding the ends of the chain to them, a difference has sometimes been made of 36 links," ($\frac{9}{2000}$) "and an average difference of 15 or 16 links to a mile" ($\frac{1}{500}$), "in common timbered land. But repeated measurements over the same mile, by the same chain men, and near the same time, will generally agree within 5 links" ($\frac{1}{1600}$); "yet, after several months' employment in the field, a measurement of this line may not agree so exactly. Again, the same chain men will make a different measurement to some extent, over swamps, marshes, wind-falls and thickets, when there is snow on the ground, and when there is none, in cold and in warm weather, effecting a change in the length of the chain, and by measuring fast or slow, the amount of error to each would be difficult to estimate."

It is seen that only in rare and favorable circumstances can a mile generally be chained within $\frac{1}{1600}$ of a second chaining. This precision of $\frac{1}{1600}$ is not more easily got by chaining, therefore, than the precision of $\frac{1}{2400}$ is got in measuring a furlong, at a single sight, with a telescope magnifying ten times; so that this telescopic measurement is at least one-half more exact than the chaining. But, as the error in reading the distance with the telescope is just as likely to enlarge as to lessen the true distance, the errors of several sights would tend to balance each other; in fact, the precision would increase as the square root of the number of sights. A mile measured in eight sights of a furlong each would be almost three times as exact as one sight, say within $\frac{1}{7000}$. A mile measured in ten sights of 528 feet each would, with the same care, be exact within about $\frac{1}{7500}$; with twenty sights of 264 feet, within $\frac{1}{11000}$, or less than six inches. The exactness with a telescope magnifying twenty times would be twice as great. The striking advantage of the instrument, then, for exactness is unquestionable; indeed, as the exactness might be still further increased by measuring a number of miles in one line, and by painting the rod in black and white (the best colors for distinct visibility, and twice as easily seen as the red marks have been reckoned), the instrument is well fitted even for quite exact geodesical measurements. The ease with which the measurements can be checked, so that large errors of reading are avoided, should also be borne in mind.

The general ease and quickness of telescopic measuring has always been recognized. The delays of chaining are saved; at the expense, however, of an addition to the telescopic work. Not only is the great trouble of training chain men avoided, but instead of two chain men with a rod, only one rodman is needed, whose duties are so simple (merely to hold the rod plumb in a good place) that he can also serve, at times, as axe-man. As the observations at the instrument are more numerous, it is the more desirable, though not absolutely necessary, in topographical work, to have an assistant to make all the readings to be noted by the head of the party.

The adjustableness, then, of the cross-hairs, and the easily legible marking of hundredths of a foot on the rod, by means of angular figures, or otherwise, make even greater exactness attainable than by Porro's improvements, without the excessive complications of his instrument, or its niceties in workmanship; and, at the same time, permits both leveling and measuring with only one rod. The rod lighted inside makes telescopic measuring and leveling easy underground, where chaining is peculiarly disagreeable. Such measuring is far more exact than chaining, as well as quicker and easier.

In the *globular* or *equidistant* projection, originated by La Hire, the eye is placed at a distance from the centre of the earth $=$ Radius $+$ sine $45^\circ = (1 + \sqrt{\tfrac{1}{2}})$ radius. The plane of projection passes through the centre perpendicular to the central ray. This projection obviates the orthographic contraction or crowding and the stereographic exaggeration in the outer rim of a projected hemisphere.

In the *stereographic* projection, the eye is taken on the surface of the earth at the pole of the great circle used as a plane of projection. Circles are stereographically projected into circles. An increasing exaggeration of parts from the centre outwards is its great defect.

In the *gnomonic* or central projection, the projection is on a tangent plane—the eye is taken at the centre of the sphere. Great circles are gnomonically projected into straight lines, and all small circles into curves of the second order or conic sections. The entire hemisphere cannot thus be projected, and the portions become rapidly exaggerated in receding from the tangent points.

CLASS II.

Instead of projecting directly on planes, an intermediate cylinder or cone is employed in this class to receive the projection which is there developed or rolled out on a tangent plane. The cylinder and cone being the only surfaces which can be developed by simple rolling out, and without elementary resolution, this class always requires the auxiliary use of one of these surfaces, which may be assumed, subject to several different conditions.

The projection on a *tangent cylinder* for development is made by placing the eye at the centre of the earth, and projecting the parallels and meridians on a cylinder tangent around the equator. On development, the parallels and meridians are found projected into perpendicular straight lines.

A *secant cylinder* may be so determined that the entire area of the spherical zone projected shall be exactly equivalent to its projection. These methods are limited in their advantageous application to a moderate equatorial belt.

In projecting perspectively on a *tangent cone* for development, the eye is assumed at the earth's centre, and the cone is taken tangent around the middle parallel of the zone to be projected. On developing this cone, the meridians appear as straight lines radiating from its vertex, and the parallels as circular arcs concentric around this point, the middle parallel being in its true length.

A *secant cone* may be taken which will give two parallels of correct length in the development, and much reduce the distortion of the extreme belts. This method of Ptolemy was revived by Mercator, and was used by De l'Isle in his map of Russia. Murdoch proposed to make the area of the conic frustrum used equal to that of the projected spherical zone—a good condition, though inconvenient in construction. De l'Isle proposed to use a cone, through the limiting parallels. Euler proposed and determined the cone which equalizes the errors and distortion on the central and the two limiting parallels. The use of two conic frustrums—one for the north and one for the south half—has also been attempted, and advocated.

CLASS III.

The class of projections in which positions of the spherical surface are developed by being resolved into their differential elements, which are successively developed, is characterized by a peculiar elegance, and is of the highest importance. By this means, any portion of a spherical or spheroidal surface may be reconstructed on a plane with the most perfect attainable preservation of the relations and dimensions of its parts. This class of projections is far the best for representing limited areas, and can even be extended with advantage in some forms to *mappe-mondes*, or maps of the entire earth's surface.

Cassini's projection is made by first developing the central meridian of the area for projection into a straight line. A series of prime verticals or great circles perpendicular to their central meridian is passed at elementary distances along the meridian arc, all of which circles intersect in the spheric poles of the central meridian. These divide the surface into elementary rectangular isosceles triangles, or sectors, basing on the meridian elements. When the meridian is developed, these elementary triangles are conceived to be carried with it, and then to be severally developed into plane triangular elements. The elementary opening out between these developed areas may be neglected for some distance from the central meridian. Accordingly, a series of perpendicular straight lines through the graduations of the developed central meridian is taken as a substitute for parallels, and may be used as far as the opening out between elements can be neglected. Cassini's Map of France is thus projected; but, as its inaccuracy on the extreme east and west sheets amounts to 150 toises in 40,000, the use of this projection is not to be recommended for areas thus extensive. Du Séjour has developed the theory and formulæ of this method. As parallels of latitude do not enter, the latitudes of places must be derived indirectly, except on the central meridian.

Flamstead's projection is based on a resolution of the earth's surface into elementary zones or rings by parallels of latitude taken at successive elementary distances laid off along the central meridian of the area to be projected. Having developed this centre meridian on a straight line of the plane of projection, a series of perpendiculars is conceived to be erected at the elementary distances along this line. On or between these perpendiculars the elementary zones are conceived to be developed in their correct relations to each other and to the central meridian. Each zone being of uniform width, occupies a constant breadth along its entire developed length, and consequently the area of the plane projection is exactly equal to that of the spheroidal surface thus developed. This demonstration applies directly to an analogous plane development of the surface of all supposable surfaces of revolution, be the generating meridian curve what it may, and even though the generatrix be one of double curvature. The meridians of the developed spheroid are traced through the same points of the parallels in which they before intersected them. They all cut the parallels obliquely, and are concave towards the central meridian. Thus, while each quadrilateral between parallels and meridians contains the same area and points after development as before, the form of configuration is considerably distorted in receding from the central meridian, and the obliquity of intersections between parallels and meridians grows to be highly unnatural.

Bonne's, or the *modified Flamstead's* projection, to a great extent obviates this defect. It is the same as Flamstead's, except that the elementary zones, instead of being developed on right lines, are rolled out on concentric circular arcs described from the vertex of the cone tangent along the central parallels for their common centre. The great importance and wide use of this method induce a more detailed treatment of it under a subjoined heading.

The *polyconic projection*, being that for which the following tables are prepared, will be specially explained further on in its proper place.

CLASS IV.

In addition to the perspective projections, the developed perspective, and the elementary development projections, there is a class in which some extraneous, arbitrary mathematical condition is imposed, giving rise to constrained or distorted delineations. The assumed condition is usually due to some practical consideration.

The *flat-chart* projection, with *equal latitude* degrees, is a rude method once much in use for charts. Two sets of equidistant perpendicular lines, composing a series of equal squares, were arbitrarily assumed as parallels and meridians to which all localities were referred by latitudes and longitudes. Hence resulted a gross distortion of figures, areas, and directions.

Another *flat-chart* projection was sometimes used, in which equidistant straight lines served as meridians; and for parallels a second set of straight perpendiculars at distances from the equator equal to those of the respective terrestrial parallels for which they stand. This is a radial projection on the circumscribing cylinder tangent along the equator, the radii of parallels being the only projecting lines. Hence resulted a very distorted picture, but one in which each quadrilateral contains an area equal to and corresponding with its spherical correlative—a direct result of the relation between the sphere and circumscribing cylinder. This was the sole recommendation of the method.

De Lorgna's projection is chiefly employed as a polar projection of a hemisphere, for which use it is well adapted. A circle is determined equivalent in area to the hemisphere to be projected. Radii drawn to the graduations of its circumference represent meridians. A radius, graduated into ninety equal parts, is sometimes used as the latitude scale; but the chords of the polar distance of the parallels should be always employed. Hence results equality of areas between the projected and resultant quadrilaterals in general. Outlines are traced by latitudes and longitudes, as usual. For projecting a polar hemisphere, this method is most excellent, as rectangular intersection is combined with conservation both of figure and area.

Ptolemy's modified conic projection is made by using the concentric parallels of the pure conic development, and tracing curved or elliptical meridians across these in place of radial lines. By turning the convexities of these curves from the central line, and by skilful choice of curves, much of the distortion due to the extension of extreme parallels in development is obviated. This projection has been much used for maps of Asia, Africa, and America.

Mercator's projection is truly invaluable for navigators in laying long courses when out of sight of land, as these courses are always straight lines on the chart. Meridians are represented by equidistant parallel straight lines, and the parallels by a perpendicular set of parallel straight lines, whose distances from each other increase from the equator towards the poles in precisely the same ratio as the corresponding longitude degrees diminish. This projection results from the development of a cylinder tangent along the equator; the meridians being projected on their tangent elements, and the parallels being assumed as circles of right cross section at distances from the equator equal to the meridian arc of latitude divided by the cosine of the latitude—the earth's compression being neglected. By this means the relation of length between the latitude and longitude measurements on the chart is preserved uniformly the same as it is on the earth's surface. Tables of the increasing degrees have been computed, and are in general use for laying down parallels. Distances and areas are increasingly exaggerated and distorted as this projection is pushed towards the pole, making the scale very variable from point to point of an extended chart; but as the navigator computes his distance run, this variable scale is not by any means so serious a defect as to offset the invaluable facility with which Mercator's principle enables him to run directly from one point to another. For the polar portion of the earth in which this projection totally fails, a central projection can be used to some distance. A projection on Mercator's principle might be made relative to the prime meridian instead of the equator, its prime verticals serving as the equidistant parallels, (as in Cassini's,) and the circles parallel to the prime meridian being projected by the table of increasing degrees. This would require the investigation of the formulæ for conversion of co-ordinates in this case. The parallels and meridians of the earth might then be constructed by points. Another mode would be to make a radial and concentric circular projection around the pole, in which the length of the latitude degree should be deduced from the same condition as in Mercator's method, the divergence of meridians being duly considered. The amount of distortion in Mercator's projection wholly unfits it for land maps; and the variation of its scale in different parts would give rise to endless inconvenience were it applied to any other purpose than that of nautical off-shore charts, in which direction is so much more important than area or distance.

BONNE'S OR THE MODIFIED FLAMSTEAD'S PROJECTION.

This method of projection is that which has been almost universally applied to the detailed topographical maps based on the trigonometrical surveys of the several States of Europe. It was originated by Bonne, was thoroughly investigated by Henry and Puissant in connexion with the map of France, and tables for France were computed by Plessis.

In constructing a map on this projection, a central meridian and a central parallel are first assumed. A cone tangent along the central parallel is assumed, the central meridian is developed on that element of this cone which is tangent to it, and the cone is then developed on a tangent plane. The parallel falls into an arc with its centre at the vertex, and the meridian into a graduated right line. Concentric circles are conceived to be traced through points of this meridian taken at elementary distances along its length. The zones of the sphere lying between the parallels through these points are next conceived to be developed each between its corresponding arcs. Thus, all the parallel zones of the sphere are rolled out on a plane in their true relations to each other and to the central meridian, each having in projection the same width, length, and relation to its neighboring zones, as on the spheroidal surface. As there are no openings between consecutive developed elements, the total area must in this case, and in all like developments of surfaces of revolution, remain wholly unaltered by the development. Each meridian of the projection is so traced as to cut each parallel in the same point in which it intersected it on the sphere.

If the case in hand be that involving the greatest extension of the method, or that of the projection of the entire spheroidal surface, a prime or central meridian must first be chosen, one half of which gives the central straight line of the development, and the other half cuts the zones apart, and becomes the outer boundary of the total developed figure. Next, the latitude of the governing parallel must be assumed; thus fixing the centre of all the concentric circles of development. Having then drawn a straight line and graduated it from 90° north latitude to 90° south latitude, and having fixed the vertex or centre of development on it, concentric arcs are traced from this centre through each graduation. On each parallel the longitude graduations are then laid off, and the meridians are traced through the corresponding points. There results from this process one oblong kidney-shaped figure, which represents the entire earth's surface, and the boundary line of which is the double developed lower half of the meridian first assumed. If the vertex of the governing cone be removed to an infinite distance, the equator becomes the governing parallel, the parallels all fall into straight lines, and Flamstead's projection results. The kidney-shaped figure becomes an elongated oval, with the half meridian for one axis, and the whole equator for the other. A somewhat similar figure is obtained by placing the vertex at the pole, and reducing the tangent cone to a plane. An indented cusp at one end, and a rounding out at the other, will give an approximate pear-shape. Ptolemy's modified conic method reaches its full geometrical result in these forms, derived from the condition of *preserving areas* in tracing meridian curves.

Bonne's method is rarely applied to areas exceeding the limits of a State, but is invaluable for topographical maps of this description. The projection is made at once for the whole territory of the map, and the rectangular system of sheets laid out on the projection. Each sheet is numbered, and the co-ordinates of the corners are determined, so that the co-ordinates of intersection between parallels and meridians falling on each sheet are referred to its neat lines as axes.

This projection preserves in all cases the areas developed without any change. The meridians intersect the central parallel at right-angles; and along this, as along the central meridian, the map is strictly correct. For moderate areas, the intersections approach tolerably to being rectangular. All distances along parallels are correct; but distances along the meridians are increased in projection in the same ratio as the cosine of the angle between the radius of the parallel and the tangent to the meridian at the point of intersection is diminished. Thus, in a full earth projection, the bounding meridian is elongated to about twice its original length. While each quadrilateral of projection preserves its area unchanged, its two diagonals become unequal; one increasing and the other diminishing in receding towards the corners of the map, the greatest inequality being towards the east and west polar corners. Though great circles between stations on the earth are generally projected into curves, the amount of deviation for moderate limits is very slight on a Bonne projection. The scale is nearly uniform over the entire projection, being accurate along the parallels and along their radii, but being too great along one diagonal of the quadrilaterals, and too small along the other. In an area of 120° longitude and 70° latitude, a distance of 7,000 miles is in error but $\frac{1}{55}$th. This projection has thus many excellent qualities for topographical maps; and its defects of oblique intersections of unequal diagonals, and of scales varying with the point of the compass, are not very serious in a limited area, as in the map of France, or that of England and Wales. A special set of tables for each central parallel is required in this method; and the extent of these is so vast as to make impracticable the conception of a universal set of tables. The French tables of Plessis are based on the parallel of $50^{gr.}$ or 45°, and are available for any area centered on this line, except that the old compression was used in computing them. But to construct tables for Bonne's projection for use in the disconnected local maps of our country was impracticable, as no central parallel could be assumed for them all. Were a general topographical map of the United States to be made, a central parallel might be assumed for that purpose; but even in this case the question should be carefully weighed, whether the Bonne projection would be as desirable as the rectangular polyconic.

THE POLYCONIC PROJECTION,* ITS PROPERTIES AND VARIETIES.

The operations of the Coast Survey being limited to a narrow belt along the seaboard, and not being intended to furnish a map of the country in regular uniform sheets, it is preferred to make an independent projection for each plane-table and hydrographic sheet, by means of its own central meridian. These sheets embrace areas so limited as to exhibit in projection no sensible distortion of figure, and they individually agree with nature far more perfectly than they would if arranged as parts of a rectangular series projected on Bonne's method. In fact, each sheet is projected strictly as a local map, and its connexion with the adjoining sheets is established solely by the points of triangulation. In reductions, including several sheets, the plotting of points is the first step, and the change of scale is then made by corresponding squares. By the aid of the subjoined tables a *rectangular polyconic* projection can at once be made for each locality or subdivision of the United States, or for the United States as a whole.

The name *rectangular polyconic* projection is applied to the method in which each parallel of the spheroid is developed symmetrically from an assumed central meridian by means of the cone tangent along its circumference. Supposing each element thus developed relative to the common central meridian, it is evident that a projection results in which all intersections of parallels and meridians take place at right-angles.

Let the most general case, or that of the entire spheroid, be first assumed, the development being made, for instance, relative to the meridian of Washington. Starting at the north pole, the tangent cone there has then its limiting form, or it coincides with the tangent plane. Taking then the elementary parallels successively southward, the vertex of the moving tangent cone recedes along the prolonged earth's axis, giving to the developed parallels a receding centre and an increasing radius as the latitude diminishes. At latitude 45° the terrestrial and development radii become equal. At the equator the vertex recedes to an infinite distance north, or the cone becomes a cylinder, and the equator falls in a straight line perpendicular to the meridian. On passing to the south the vertex approaches from an infinite distance south, the parallels change their concavity southward, while the curvature, increasing in an inverse order, becomes infinite at the pole, or the polar parallel falls in a point. There results from this process a biaxial figure, with four equal quadrants, the short axis being the rectified Washington meridian, (180° in length) and the long axis being the entire rectified equator, or about twice the length of the shorter one. A re-entering cusp marks the bounding curve at each pole, and the meridian, 180° from Washington, which circumscribes each half of the figure, is elongated on each side to more than twice its original length by the development. Over the entire area of this projection all parallels and meridians intersect at right-angles, and the diagonals of each projected quadrilateral are everywhere nearly equal to each other. The scale on N. and S. lines near the border is somewhat enlarged, but is very correct on E. and W. lines, while along both diagonals it is somewhat enlarged, though nearly equally so on each. On the whole there results from this method much less of local distortion than from Bonne's projection. Equality between the spheroidal and developed areas is not preserved, but the departure from equivalency is not great in amount.

As rectangular intersections and preservation of areas are not both attainable at once, it becomes a question of preference between them in each case. It is also a question whether it might not in some cases be advantageous still further to sacrifice the preservation of areas so as to make the same scale applicable in all azimuths at each point. This would require the longitude degrees to increase from the centre meridian outwards in the same ratio as the corresponding projected meridional degrees. This condition would determine a new polyconic projection, whose scale, from point to point, (an element which in Bonne's, and the simple polyconic projection, is a function both of the central meridian distance, and azimuth) would become a function of the central meridian distance only, and would increase alike in all directions on receding from this line. Such a projection would reduce distortion of local configuration to an absolute minimum, and the areas in projection would be proportional to the squares of their local graphic degrees. This would enable us to take strict account of those irregularities of scale which now lurk in disguise. But it would be a great labor to prepare the tables requisite for its ready use, and there would be some valid objections to its results. In a large topographical map thus projected, the scale of each sheet could be derived and engraved on its plate, making the sheet quite homogeneous on that scale, and perfect in the preservation of its configuration. Were a topographical map of the United States to be undertaken on a liberal scale, this projection might be found superior to any other, as in each sheet areas, dimensions, relations, and rectangular intersections, would be well preserved according to its own scale, giving it the greatest local perfection, while it would also combine correctly in its proper place. It should be stated that this projection is novel and untried.

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*It is hoped at some future time to present some further information on the history of the polyconic projection, and on the applications of it which have been made, the materials now available for this purpose being too limited to authorize attempting this branch of the subject.

The method of projection in common use in the Coast Survey office for small areas, such as those of plane-table and hydrographic sheets, may be called the *equidistant polyconic*. This ought to be regarded rather as a convenient graphic approximation, admissible within certain limits, than as a distinct projection, though it is capable of being extended to the largest areas, and with results quite peculiar to itself. In constructing such a projection the central meridian and a central parallel are chosen, and they are constructed just as in the rectangular polyconic method. The top or bottom parallel, and a sufficient number of intermediate ones to determine the meridians with proper correctness, are constructed by the tables, and the meridians are drawn. Then starting from the central parallel, the distance to the next parallel is taken from the central meridian and laid off on each other meridian. A parallel is traced through the points thus found. Each parallel is constructed by laying off equal distances on the meridians in like manner, and the tabular auxiliary parallels are, all except the central one, erased. In fact, as only the points of intersection are required, the auxiliary parallels should not be actually drawn. From this process of construction results a projection in which equal meridian distances are everywhere intercepted between the same parallels.

If we conceive this projection extended to include the entire earth, a singular result appears. Taking the equator as the central parallel, all the parallels become concave towards this line; for the distance between parallels measured along the curved meridians being constructed equal to that along the central straight meridian, it is evident that the parallels must converge in receding from the central meridian. The parallel of 90°, or the polar point, becomes extended into a curve, whose length approaches that of the developed equator. It will be seen that each parallel falls nearer the equator than it would in Flamstead's projection, being, indeed, tangent on the equatorial side of the Flamstead perpendicular. Thus, in this method the projected area is less than that of the spheroidal surface. If an equidistant polyconic projection be made on the same central meridian and parallel as a Bonne projection, its area will in like manner be less for each rectangle and for the aggregate; hence this projection, where extended to a great surface, always gives its area too small. It also makes its meridian arcs unduly short, and the extreme parallels much too long; giving a grotesqueness to the polar regions bordering on that of a Mercator projection. The scale becomes in some parts excessively dependent on azimuth; the distortion in the polar corners is very great; the intersections are far from rectangular, and they are so conditioned as not to be readily computed. From these defects, so gross in the developed spheroid, and still great even in a map of the United States, it is clear that the *polyconic-equidistant* projection ought by no means to be extended beyond the most moderate limits. A square degree, on a scale of $\frac{1}{10000}$, may be taken as a limit, beyond which no convenience of graphic construction should induce the use of this approximation. Beyond this limit the *rectangular-polyconic* method should be employed, at least in all Coast Survey projections.

The polyconic method of projection has been developed in the Coast Survey office, and the subjoined tables, prepared for facilitating its use, were there computed, and are now first published.

Formulæ used for the computation of the Projection Tables in use at the Coast Survey office.

The data upon which the tables are founded are derived from a discussion of the magnitude and figure of the earth, commenced by Mr. Bessel in "Schumacher's Astronomishe Nachrichteu," No. 333, and continued and corrected in No. 438 of the same work by the same writer.

Formulæ for calculating the elements for the projection of maps

Let a be the equatorial radius;

b the polar radius;

e the eccentricity $=\sqrt{1-\frac{b^2}{a^2}}$;

L the geodetic latitude;

D_m the length, in metres, of a meridional degree;

D_p the length, in metres, of a degree of the parallel;

R_m the radius of curvature in the meridian;

R_p the radius of curvature in the parallel.

Then,

$$R_m=\frac{a(1-e^2)}{(1-e^2\sin^2 L)^{\frac{3}{2}}}=\frac{1}{B\sin 1''}\qquad B=\frac{(1-e^2\sin^2 L)^{\frac{3}{2}}}{a(1-e^2)\sin 1''},\qquad B=\frac{1}{R_m\sin 1''}$$

$$R_p=\frac{a\cos L}{(1-e^2\sin^2 L)^{\frac{1}{2}}}=\frac{\cos L}{A\sin 1''}\qquad A=\frac{(1-e^2\sin^2 L)^{\frac{1}{2}}}{a\sin 1''}\qquad A=\frac{\cos L}{R_p\sin 1''}$$

Length of a minute in the meridian $=60\,R_m\sin 1''=\frac{60}{B}$.

Length of a minute in the parallel $=60\,R_p\sin 1''=\frac{60\cos L}{A}$.

Tables containing the values of A and B have been computed in this office, forming a part of tables for the computation for differences of geodetic latitudes, longitudes, and azimuths.

The following formulæ may also be used:

$$D_m=111120^{m}.619-558^{m}.080\cos 2L+1^{m}.168\cos 4L-0^{m}.002\cos 6L;$$

$$D_p=111399^{m}.675\cos L-93^{m}.212\cos 3L+0.116\cos 5L;$$

or, making $\sin L'=e\sin L$;

$$\log D_p=5.0465208+\log.\cos L-\log.\cos L'.$$

Table of constants and their logarithms.

	Logarithms.
$a = 3272077.14$ toises	6.5148235337
$b = 3261139.33$ toises	6.5133693539
1 toise = 1.94903631 metres, (December 10, 1799)	0.2898199300
1 metre = 0.513074074 toises	9.7101800700
$a = 6377397.16$ metres	6.8046434637
$b = 6356078.96$ metres	6.8031892839
$a : b :: 299.1528 : 298.1528$	
$e = 0.081696830$	8.9122052
$e^2 = 0.006674372$	7.8244104
$a^2 = 40671194485356$ metre sq	13.6092869274
$b^2 = 40399739783891$ metre sq	13.6063785678
arc 1″ or sin 1″	4.6855748668
$a\,(1 - e^2)$	6.8017351
111120.619	5.0457946543
111399.675	5.0468839231
$a \sin 1''$	1.4902183305

For the curvature of the parallels we have the following formulæ:

$$\text{Radius of curvature equal tangent ending on the minor axis} = \frac{a \operatorname{cotg} L}{(1 - e^2 \sin^2 L)^{\frac{1}{2}}}.$$

For convenience sake, co-ordinates for the curvature have been computed:

Let x' be the abscissa from the principal meridian;
y the corresponding ordinate;
n the number of minutes of longitude; and
$\frac{1}{2}\theta$ the corresponding angle between the tangent and the chord, at the intersection of the parallel and middle meridian.

Then,

$$\sin \tfrac{1}{2}\theta = 30\, n \sin L \sin 1'';$$

$$x_{\prime} = 60\; n\; R_p \sin 1'' \cos \tfrac{1}{2}\theta;$$

$$y = 60\; n\, R_p \sin 1'' \sin \tfrac{1}{2}\, \theta;$$

n minutes on the arc of parallel $= 60\, n\, R_p \sin 1''$, and subtracting $x_{\prime}$ we obtain $x =$ difference $= (1 - \cos \frac{1}{2}\, \theta)\, 60\, n\, R_p \sin 1''$. This quantity x is to be laid off in a direction towards the middle meridian; x and y may be expressed in the following convenient form for computation:

$$y = \frac{1800\, n^2 \sin L \cos L \sin 1''}{A};$$

$$x = y\,(15\, n \sin L \sin 1'');$$

which latter formula is very nearly strict; the error $\frac{x^3}{y^2}$ is not perceptible in any of the maps in use. In order to lay off more accurately the lengths of arcs on the parallels in large projections, the length of the chord may be computed.

Explanation of the tables.

TABLE I.—This is a table of constants, for use in the conversion of units.

TABLE II.—To facilitate the conversion of—
- A. Metres into statute miles, from 1 to 100,000.
- B. Statute miles into metres, from 1 to 100.
- C. Metres into yards, from 1 to 100,000.
- D. Yards into metres, from 1 to 100,000.
- E. Yards into statute miles, from 1 to 100,000.

TABLE III.—Length of a meridian degree for each 5° of latitude, from 20° to 50° latitude, expressed in statute and nautical miles.

TABLE IV.—Length of a longitude degree on each degree parallel, from 17° to 50° latitude, expressed in—
- A. Nautical miles.
- B. Statute miles.
- C. Metres.

TABLE V.—For use in projecting maps covering an extended area. It gives the requisite values of the meridian and parallel arcs, (Table V—A) and of X and of Y, (Table V—B) for 70° in total longitude, on each degree parallel of latitude from 17° to 50° latitude. Taking the meridian of Galveston, or 95° W. of Greenwich, for the central meridian, this table extends 35° E. and 35° W. of it, or from longitude 60° to longitude 130° W. of Greenwich. This embraces the entire United States, Nova Scotia, and about 5° of the Pacific ocean, in the northern United States latitudes. The southern limit, latitude 17°, includes the four principal West India Islands; and the northern limit, latitude 50°, embraces a narrow belt of British America. For projections of so great an extent, the successive parallels and meridians will not be less than a degree apart. This table will be found to suffice for extended maps of the United States, in whole or in part. When a more detailed projection is required, and in all cases of local maps, recourse should be had to the following table:

TABLE VI.—This table presents the requisite lengths of latitude and longitude arcs on meridians, and on parallels, with the corresponding values of X and of Y, for all local projections of large scale, which can be desired between the parallels 24° and 50°. The arcs of parallels are given to seconds for each minute of latitude, and the other elements to a corresponding degree of accuracy. The minuter arcs being only required in using large scales, it was unnecessary further to extend the arcs of parallels. Interpolations may be resorted to if desired.

In Tables V and VI, the arcs on each page, from 1″ to 6″ of longitude, are obtained by shifting the decimal point one place to the left, in the columns from 10″ to 60″.

Graphic construction of polyconic projections—Coast Survey methods.

Having fixed the limits to be covered by the projection, the central meridian is represented by a straight line, as nearly as practicable, through the centre of the sheet. From an assumed starting-point on this line are laid off the successive meridian arcs, as taken from the tables.

Rectangular polyconic method.

Through each point of division on the central meridian, given by these tabular arcs, erect a perpendicular to it by means of a well-tested right-angled ruler, with twenty-four-inch legs, and a hard pencil; or first carefully construct a single accurate perpendicular by sweeping intersecting arcs with the beam-compass, and then draw on each side a parallel to the central meridian, on which lay off the meridian distance from the perpendicular, and draw the parallel lines through the three equidistant points thus obtained for each. Take from the tables for each required point of intersection between parallels and meridians, its appropriate length of arc of parallel, from which subtract the corresponding X. Lay off this difference from the central meridian each way on its proper perpendicular, and erect, towards the pole, at the point so formed, a perpendicular equal to the corresponding value of Y in the tables—its extremity is the point of intersection required. Through all the corresponding points of intersection trace the parallels and the meridians. Erase the auxiliary lines, and write on the margin the numerical latitude and longitude.

The following mode is more rapid and better checked: Lay off first the longest arcs of parallel, and then take the length of a single subdivision of the parallel in a pair of hair-spring dividers, and step it off on the perpendicular to the right and left of the central meridian, being careful not to prick the paper. Having adjusted the dividers so as to bring the extreme points thus obtained to a perfect agreement, prick lightly the subdivision points. Take from the tables the successive values of X for each point, and when these are sensible on the scale used, lay them off back towards the central meridian from the points before obtained, and erect, at the last points, perpendiculars equal to their respective values of Y. As X is always small, and for some entire projections quite insensible, this method is much more convenient than that of all the while using long distances; but the check of a total measurement on each parallel is quite indispensable, as an insensible error in taking the subdivision distances grows, by repetition, to be very evident in the check measurement.

Equidistant polyconic method—(☞ Inadmissible in projections covering more than one square degree.) Proceed as before to graduate the central meridian, and to construct a central parallel. Construct the points of meridian intersection with the top and bottom parallels, and as many intermediate parallels as are requisite closely to determine the meridians. Through these points then draw the meridians. Starting now from the central parallel, lay off on each meridian the distance to the required parallel equal to that on the central meridian, and trace the parallels through these points. Proceed in like manner to construct the others, using always the central parallel as a base, and the totals measured from it along the central meridian in laying off.

This method requires much less recourse to the tables than the other, and is sufficiently accurate, within a square degree, on a scale of $\frac{1}{10000}$. The X and Y may often be neglected as insensible in small projections; but no value of X, which is at all appreciable on the scale used, should be neglected. The Y, for the auxiliary parallels, affects the meridian less rapidly, but its palpably sensible values should always be used.

The following quantities are sensible, yet only barely sensible, on the scales affixed:

12 metres on a scale of $\frac{1}{80000}$.
10 " " $\frac{1}{60000}$.
8 " " $\frac{1}{40000}$.
6 or 5 " " $\frac{1}{30000}$.
3 " " $\frac{1}{20000}$.
1½ or 2 " " $\frac{1}{10000}$.

These quantities are quite overshadowed in large sheets by the expansion and shrinkage of drawing-paper from day to day. In both methods the X and Y should always be used for good projections when they would be sensible on the scale in use. And it is peculiarly essential to accurate projections that the hygrometric condition of the paper be kept as uniform as possible during all the time that measured distances are being laid down. It is often better to mark simply the intersection points by a small cross +, and to omit the remainder of the parallels and meridians. For plotted points this is also the best indication, if the cross lines are stopped on each side of the point, just far enough off to leave the dot distinct.

For drawing parallels and meridian curves a long, slender, flexible ruler of straight-grained cedar, or other compact wood, is employed. Its cross section is three sixteenths ($\frac{3}{16}$) of an inch by two sixteenths ($\frac{2}{16}$) of an inch. A specially designed steel ruler might be found preferable. There is a small groove on the top of the ruler, and its ruling edge is slightly levelled. Leaden, paper-covered, beak weights, of about 4 pounds weight each, are used to hold the ruler in place from point to point. These are so shaped as not to incommode the hand in ruling, and each has a hooked beak, ending in a knife-edge, turned downwards, which, resting in the ruler groove, throws the main bearing of the weight on the ruler, while its small end rests on the paper. The beak weights in use are five (5) inches long, two and one-eighth (2⅛) wide, and two and one-eighth (2⅛) deep, the beak being five-eighths (⅝) of an inch long, and turned down one-fourth (¼) inch. The mass of lead is nearer the beak end. Having placed the ruler approximately, it is so adjusted under a beak weight to the first point that the curve will be ruled exactly through it. It is then adjusted under a second weight to the next point, and then bent to the next in like manner, and so on until the entire curve is completed. Before ruling this the eye should criticise it carefully, as a check on graphic errors. For fine projections the hardest pencils are best; and in inking, the lines should be drawn as delicately as clearness permits.

When no metre scale is at hand, the tabulated distances can be converted into yards by Table II, or by the constants of Table I; or, when the greatest accuracy is not important, a metre scale can readily be constructed from a yard or foot scale by proportionality. Thus, rule two parallel scales, one of yards and one of five-sixths ($\frac{5}{6}$) yards, and draw a third parallel, whose distance outside the yard scale is $\frac{3 \cdot 3685}{6}$ th of that between the yard and five-sixths yard scales. Through the similar graduations draw straight lines; these will give a metre scale by their intersections. If space permits, a point may be substituted for the five-sixths ($\frac{5}{6}$) yard scale. The projection once constructed, may be used independent of the unit of the tables.

TABLE I.

Relation between the measures of length used in different countries.

Derived from 1 metre at 32° Fah. = 39. 36850535 U. S. standard inches at 62° Fah.

Units.	American feet.	English feet.	Metres.
American yard	3.	3. 00017409	0. 91443654
American foot	1.	1. 00005803	0. 30481218
English yard	2. 99982591	3.	0. 91438347
English foot, (Kater's value)	0. 99994197	1.	0. 30479449
Metre	3. 28070878	3. 28089917	1.
French toise	6. 394219	6. 394590	1. 9490366

TABLE II.—A.

Table for converting metres into statute miles.

1 metre = 0. 000621346 mile.

[6. 7933335.]

Metres.	Miles.	Metres.	Miles.	Metres.	Miles.	Metres.	Miles.
100000	62. 135						
90000	55. 921	9000	5. 592	900	0. 559	90	0. 056
80000	49. 708	8000	4. 971	800	0. 497	80	0. 050
70000	43. 494	7000	4. 349	700	0. 435	70	0. 044
60000	37. 281	6000	3. 728	600	0. 373	60	0. 037
50000	31. 067	5000	3. 107	500	0. 311	50	0. 031
40000	24. 854	4000	2. 485	400	0. 249	40	0. 025
30000	18. 640	3000	1. 864	300	0. 186	30	0. 019
20000	12. 427	2000	1. 243	200	0. 124	20	0. 012
10000	6. 213	1000	0. 621	100	0. 062	10	0. 006

TABLE II.—B.

Table for converting statute miles into metres.

1 mile = 1609. 40831 metres.

[3. 2066665.]

Miles.	Metres.	Miles.	Metres.	Miles.	Metres.	Miles.	Metres.
100	160940. 83						
90	144846. 75	9	14484. 68	0. 9	1448. 47	0. 09	144. 85
80	128752. 66	8	12875. 27	0. 8	1287. 53	0. 08	128. 75
70	112658. 58	7	11265. 86	0. 7	1126. 59	0. 07	112. 66
60	96564. 50	6	9656. 45	0. 6	965. 65	0. 06	96. 56
50	80470. 41	5	8047. 04	0. 5	804. 70	0. 05	80. 47
40	64376. 33	4	6437. 63	0. 4	643. 76	0. 04	64. 38
30	48282. 25	3	4828. 23	0. 3	482. 82	0. 03	48. 28
20	32188. 17	2	3218. 82	0. 2	321. 88	0. 02	32. 19
10	16094. 08	1	1609. 41	0. 1	160. 94	0. 01	16. 09

TABLE II.—C.

Table for converting metres into yards.

1 metre = 1. 09356959 yard.

[0. 0388464.]

Metres.	Yards.	Metres.	Yards.	Metres.	Yards.	Metres.	Yards.	Metres.	Yards.
100000	109356. 96								
90000	98421. 26	9000	9842. 13	900	984. 21	90	98. 42	9	9. 84
80000	87485. 57	8000	8748. 56	800	874. 86	80	87. 49	8	8. 75
70000	76549. 87	7000	7654. 99	700	765. 50	70	76. 55	7	7. 65
60000	65614. 18	6000	6561. 42	600	656. 14	60	65. 61	6	6. 56
50000	54678. 48	5000	5467. 85	500	546. 79	50	54. 68	5	5. 47
40000	43742. 78	4000	4374. 28	400	437. 43	40	43. 74	4	4. 37
30000	32807. 09	3000	3280. 71	300	328. 07	30	32. 81	3	3. 28
20000	21871. 39	2000	2187. 14	200	218. 71	20	21. 87	2	2. 19
10000	10935. 70	1000	1093. 57	100	109. 36	10	10. 94	1	1. 09

TABLE II.—D.

Table for converting yards into metres.

1 yard = 0. 91443654 metre.

[9. 9611536.]

Yards.	Metres.	Yards.	Metres.	Yards.	Metres.	Yards.	Metres.	Yards.	Metres.
100000	91443. 65								
90000	82299. 29	9000	8229. 93	900	822. 99	90	82. 30	9	8. 23
80000	73154. 92	8000	7315. 49	800	731. 55	80	73. 16	8	7. 32
70000	64010. 56	7000	6401. 06	700	640. 11	70	64. 01	7	6. 40
60000	54866. 19	6000	5486. 62	600	548. 66	60	54. 87	6	5. 49
50000	45721. 83	5000	4572. 18	500	457. 22	50	45. 72	5	4. 57
40000	36577. 46	4000	3657. 75	400	365. 78	40	36. 58	4	3. 66
30000	27433. 10	3000	2743. 31	300	274. 33	30	27. 43	3	2. 74
20000	18288. 73	2000	1828. 87	200	182. 89	20	18. 29	2	1. 83
10000	9144. 37	1000	914. 44	100	91. 44	10	9. 14	1	0. 91

TABLE II.—E.

Table for converting yards into miles.

1 yard = 0. 000568182 mile.

[6. 7544873.]

Yards.	Miles.	Yards.	Miles.	Yards.	Miles.	Yards.	Miles.
100000	56. 818						
90000	51. 136	9000	5. 114	900	0. 511	90	0. 051
80000	45. 455	8000	4. 545	800	0. 455	80	0. 045
70000	39. 773	7000	3. 977	700	0. 398	70	0. 040
60000	34. 091	6000	3. 409	600	0. 341	60	0. 034
50000	28. 409	5000	2. 841	500	0. 284	50	0. 028
40000	22. 727	4000	2. 273	400	0. 227	40	0. 023
30000	17. 045	3000	1. 705	300	0. 170	30	0. 017
20000	11. 364	2000	1. 136	200	0. 114	20	0. 011
10000	5. 682	1000	0. 568	100	0. 057	10	0. 006

TABLE III.

Length of a degree of the meridian, in nautical and statute miles, for each fifth degree of latitude between 20° and 50°.

1° of latitude.	In latitude—	1° of latitude.
Nautical miles.		*Statute miles.*
59. 669	20°	68. 779
59. 706	25	68. 822
59. 749	30	68. 871
59. 796	35	68. 925
59. 847	40	68. 984
59. 899	45	69. 044
59. 951	50	69. 104

TABLE IV.—A.

Length of a degree of longitude between the parallels of 17° and 50°, for each degree of latitude, expressed in nautical miles.

1° of longitude.	In latitude—		1° of longitude.
Nautical miles.			*Nautical miles.*
57. 395	17°	34°	49. 794
57. 082	18	35	49. 203
56. 751	19	36	48. 597
56. 404	20	37	47. 976
56. 039	21	38	47. 341
55. 657	22	39	46. 690
55. 259	23	40	46. 026
54. 843	24	41	45. 348
54. 411	25	42	44. 656
53. 962	26	43	43. 949
53. 497	27	44	43. 230
53. 016	28	45	42. 498
52. 518	29	46	41. 752
52. 005	30	47	40. 993
51. 476	31	48	40. 222
50. 931	32	49	39. 439
50. 370	33	50	38. 643

1° of longitude at the equator = 60 nautical miles.
" " = 111306. 6 metres.
" " = 121721. 4 yards.
" " = 69. 160 statute miles.

TABLE IV.—B.

Length of a degree of longitude between the parallels of 17° and 50°, for each degree of latitude, expressed in statute miles.

1° of longitude.	In latitude—		1° of longitude.
Statute miles.			*Statute miles.*
66.157	17°	34°	57.396
65.796	18	35	56.715
65.415	19	36	56.016
65.015	20	37	55.300
64.594	21	38	54.568
64.154	22	39	53.819
63.695	23	40	53.053
63.216	24	41	52.271
62.718	25	42	51.473
62.200	26	43	50.659
61.664	27	44	49.830
61.109	28	45	48.986
60.536	29	46	48.126
59.944	30	47	47.251
59.334	31	48	46.362
58.706	32	49	45.460
58.060	33	50	44.542

TABLE V.—A.

Length, in metres, of 1° of latitude and longitude, for each degree of latitude between 17° and 50°.

1° of latitude.	1° of longitude.	Latitude.		1° of longitude.	1° of latitude.
Metres.	*Metres.*			*Metres.*	*Metres.*
110,658.4	106,473.4	17°	34°	92,373.8	110,910.7
110,669.5	105,892.6	18	35	91,277.3	110,928.8
110,681.1	105,279.7	19	36	90,152.9	110,947.2
110,693.3	104,634.8	20	37	89,001.0	110,965.8
110,706.0	103,958.2	21	38	87,821.9	110,984.6
110,719.2	103,250.0	22	39	86,616.0	111,003.5
110,732.9	102,510.5	23	40	85,383.6	111,022.6
110,747.1	101,739.8	24	41	84,125.1	111,041.8
110,761.7	100,938.2	25	42	82,840.8	111,061.1
110,776.7	100,105.9	26	43	81,531.1	111,080.5
110,792.2	99,243.2	27	44	80,196.5	111,100.0
110,808.1	98,350.2	28	45	78,837.3	111,119.4
110,824.4	97,427.4	29	46	77,453.9	111,138.9
110,841.0	96,474.8	30	47	76,046.8	111,158.4
110,858.0	95,492.9	31	48	74,616.3	111,177.8
110,875.2	94,481.9	32	49	73,162.9	111,197.2
110,892.8	93,442.1	33	50	71,687.0	111,216.4

TABLE V.—B.

Co-ordinates of curvature for each degree of longitude, from 1° to 35°, between the latitudes 17° and 50°.

Degrees of longitude.	Latitude 17°.		Latitude 18°.		Latitude 19°.		Latitude 20°.		Latitude 21°.		Latitude 22°.		Latitude 23°.	
	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.
°	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*
1	0	272	0	286	0	299	0	312	1	325	1	338	1	350
2	3	1, 087	3	1, 142	3	1, 196	4	1, 249	4	1, 300	4	1, 350	5	1, 398
3	9	2, 445	10	2, 570	11	2, 692	13	2, 811	14	2, 926	15	3, 038	16	3, 146
4	22	4, 347	25	4, 569	27	4, 786	30	4, 997	33	5, 202	35	5, 400	38	5, 593
5	43	6, 792	48	7, 139	53	7, 478	58	7, 808	64	8, 127	69	8, 438	75	8, 738
6	75	9, 780	83	10, 280	92	10, 768	101	11, 243	110	11, 704	119	12, 151	129	12, 583
7	119	13, 311	132	13, 992	146	14, 657	160	15, 303	174	15, 931	189	16, 539	204	17, 127
8	178	17, 386	197	18, 276	218	19, 143	239	19, 987	260	20, 807	282	21, 602	305	22, 370
9	253	22, 004	281	23, 130	310	24, 228	339	25, 296	370	26, 334	402	27, 340	435	28, 312
10	347	27, 166	385	28, 556	425	29, 911	466	31, 230	509	32, 511	552	33, 753	596	34, 954
11	461	32, 871	512	34, 552	566	36, 193	620	37, 789	677	39, 339	734	40, 841	793	42, 294
12	599	39, 119	666	41, 120	734	43, 072	805	44, 972	879	46, 816	953	48, 604	1, 030	50, 333
13	762	45, 910	846	48, 260	934	50, 550	1, 024	52, 779	1, 117	54, 944	1, 212	57, 043	1, 310	59, 072
14	951	53, 245	1, 056	55, 970	1, 166	58, 626	1, 279	61, 211	1, 395	63, 722	1, 514	66, 156	1, 635	68, 510
15	1, 170	61, 123	1, 300	64, 251	1, 434	67, 300	1, 573	70, 268	1, 716	73, 150	1, 862	75, 944	2, 011	78, 646
16	1, 420	69, 545	1, 577	73, 103	1, 740	76, 573	1, 909	79, 950	2, 082	83, 229	2, 260	86, 408	2, 441	89, 482
17	1, 703	78, 510	1, 892	82, 526	2, 088	86, 443	2, 290	90, 255	2, 498	93, 958	2, 711	97, 546	2, 928	101, 016
18	2, 021	88, 017	2, 246	92, 521	2, 478	96, 912	2, 719	101, 186	2, 965	105, 337	3, 218	109, 360	3, 475	113, 250
19	2, 377	98, 069	2, 641	103, 087	2, 914	107, 980	3, 197	112, 741	3, 487	117, 366	3, 784	121, 849	4, 087	126, 183
20	2, 772	108, 664	3, 080	114, 224	3, 399	119, 645	3, 729	124, 921	4, 067	130, 045	4, 414	135, 013	4, 767	139, 815
21	3, 210	119, 801	3, 566	125, 932	3, 935	131, 909	4, 316	137, 725	4, 708	143, 375	5, 110	148, 851	5, 519	154, 146
22	3, 690	131, 483	4, 100	138, 207	4, 524	144, 770	4, 963	151, 155	5, 413	157, 355	5, 875	163, 364	6, 345	169, 176
23	4, 217	143, 708	4, 685	151, 061	5, 170	158, 230	5, 671	165, 210	6, 185	171, 985	6, 713	178, 554	7, 251	184, 905
24	4, 791	156, 475	5, 323	164, 482	5, 874	172, 289	6, 443	179, 886	7, 028	187, 266	7, 627	194, 418	8, 238	201, 334
25	5, 415	169, 787	6, 016	178, 474	6, 639	186, 945	7, 282	195, 189	7, 913	203, 196	8, 620	210, 957	9, 312	218, 461
26	6, 091	183, 641	6, 767	193, 038	7, 468	202, 200	8, 192	211, 116	8, 935	219, 777	9, 697	228, 171	10, 474	236, 287
27	6, 821	198, 040	7, 579	208, 172	8, 364	218, 052	9, 174	227, 668	10, 006	237, 008	10, 859	246, 060	11, 730	254, 813
28	7, 608	212, 980	8, 452	223, 878	9, 328	234, 564	10, 231	244, 845	11, 160	254, 889	12, 111	264, 624	13, 082	274, 037
29	8, 452	228, 465	9, 391	240, 155	10, 363	251, 553	11, 367	262, 646	12, 399	273, 421	13, 455	283, 863	14, 534	293, 961
30	9, 357	244, 493	10, 396	257, 003	11, 472	269, 201	12, 584	281, 072	13, 726	292, 602	14, 896	303, 777	16, 090	314, 584
31	10, 324	261, 064	11, 470	274, 422	12, 658	287, 447	13, 885	300, 122	15, 145	312, 434	16, 436	324, 367	17, 753	335, 906
32	11, 356	278, 180	12, 617	292, 412	13, 923	306, 291	15, 272	319, 797	16, 658	332, 916	18, 078	345, 631	19, 527	357, 926
33	12, 454	295, 837	13, 837	310, 973	15, 270	325, 733	16, 749	340, 097	18, 270	354, 049	19, 827	367, 571	21, 416	380, 646
34	13, 621	314, 038	15, 133	330, 106	16, 700	345, 774	18, 318	361, 022	19, 981	375, 832	21, 684	390, 185	23, 422	404, 065
35	14, 859	332, 782	16, 508	349, 809	18, 218	366, 413	19, 982	382, 570	21, 796	398, 264	23, 654	413, 475	25, 550	428, 183

TABLE V—B.—*Co-ordinates of curvature for each degree of longitude, &c.*—Continued.

Degrees of longitude.	Latitude 24°.		Latitude 25°.		Latitude 26°.		Latitude 27°.		Latitude 28°.		Latitude 29°.		Latitude 30°.	
	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.
°	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*
1	1	361	1	372	1	383	1	393	1	403	1	412	1	421
2	5	1,445	5	1,489	6	1,532	6	1,573	7	1,612	7	1,649	7	1,684
3	17	3,250	19	3,350	20	3,447	21	3,539	22	3,626	24	3,710	25	3,789
4	41	5,778	44	5,956	47	6,127	50	6,291	53	6,447	56	6,595	59	6,735
5	80	9,028	86	9,307	92	9,574	97	9,830	103	10,073	109	10,305	115	10,524
6	138	13,000	148	13,401	158	13,786	168	14,154	178	14,506	188	14,839	198	15,154
7	220	17,695	235	18,241	251	18,765	267	19,266	283	19,744	299	20,198	315	20,627
8	328	23,112	351	23,825	375	24,509	399	25,164	423	25,788	446	26,380	470	26,941
9	467	29,251	500	30,153	534	31,020	568	31,848	602	32,638	636	33,388	669	34,097
10	641	36,112	686	37,226	732	38,296	779	39,319	825	40,293	872	41,219	918	42,095
11	853	43,696	914	45,044	975	46,338	1,037	47,575	1,099	48,755	1,161	49,875	1,222	50,935
12	1,107	52,001	1,186	53,606	1,266	55,146	1,346	56,618	1,426	58,022	1,507	59,356	1,587	60,617
13	1,408	61,029	1,508	62,913	1,609	64,720	1,711	66,448	1,813	68,096	1,916	69,660	2,018	71,141
14	1,759	70,780	1,884	72,964	2,010	75,060	2,137	77,064	2,265	78,975	2,393	80,789	2,520	82,506
15	2,163	81,252	2,317	83,759	2,472	86,165	2,629	88,466	2,786	90,660	2,943	92,743	3,100	94,714
16	2,625	92,447	2,816	95,300	3,000	98,037	3,190	100,655	3,381	103,151	3,571	105,521	3,762	107,763
17	3,149	104,364	3,372	107,584	3,600	110,674	3,827	113,630	4,055	116,447	4,284	119,123	4,512	121,655
18	3,738	117,003	4,003	120,614	4,272	124,078	4,542	127,392	4,814	130,550	5,085	133,550	5,356	136,388
19	4,396	130,364	4,708	134,387	5,024	138,247	5,342	141,940	5,661	145,459	5,981	148,801	6,299	151,963
20	5,127	144,449	5,492	148,906	5,860	153,182	6,231	157,273	6,603	161,173	6,976	164,877	7,347	168,380
21	5,935	159,254	6,357	164,167	6,784	168,884	7,213	173,394	7,644	177,693	8,075	181,777	8,505	185,639
22	6,824	174,782	7,309	180,176	7,800	185,351	8,293	190,300	8,789	195,019	9,284	199,501	9,779	203,740
23	7,798	191,033	8,352	196,928	8,912	202,584	9,476	207,994	10,066	213,151	10,609	218,050	11,174	222,683
24	8,860	208,005	9,490	214,424	10,126	220,583	10,767	226,473	11,410	232,089	12,054	237,423	12,696	242,468
25	10,014	225,700	10,726	232,665	11,445	239,348	12,170	245,739	12,897	251,833	13,624	257,620	14,349	263,094
26	11,264	244,117	12,065	251,651	12,874	258,878	13,689	265,792	14,507	272,382	15,325	278,642	16,141	284,563
27	12,615	263,257	13,512	271,381	14,418	279,175	15,330	286,630	16,246	293,738	17,162	300,488	18,076	306,873
28	14,069	283,118	15,069	291,855	16,080	300,238	17,097	308,255	18,119	315,899	19,141	323,160	20,160	330,026
29	15,631	303,702	16,742	313,074	17,865	322,066	18,995	330,667	20,130	338,866	21,266	346,654	22,398	354,019
30	17,304	325,008	18,535	335,038	19,778	344,660	21,029	353,865	22,286	362,639	23,542	370,973	24,796	378,856
31	19,093	347,036	20,450	357,746	21,822	368,021	23,203	377,849	24,589	387,218	25,976	396,117	27,359	404,534
32	21,001	369,787	22,494	381,199	24,003	392,147	25,522	402,620	27,046	412,603	28,572	422,085	30,093	431,053
33	23,031	393,260	24,669	405,396	26,324	417,039	27,990	428,176	29,662	438,793	31,335	448,877	33,004	458,416
34	25,190	417,455	26,981	430,337	28,790	442,697	30,612	454,520	32,441	465,790	34,271	476,494	36,096	486,619
35	27,478	442,372	29,432	456,024	31,406	469,121	33,394	481,649	35,389	493,592	37,385	504,935	39,375	515,665

TABLE V—B.—*Co-ordinates of curvature for each degree of longitude, &c.*—Continued.

Degrees of longitude.	Latitude 31°.		Latitude 32°.		Latitude 33°.		Latitude 34°.		Latitude 35°.		Latitude 36°.		Latitude 37°.	
	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.
o	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres*	*Metres.*	*Metres.*
1	1	429	1	437	1	444	1	451	1	457	1	462	1	468
2	8	1,717	8	1,748	8	1,776	9	1,803	9	1,827	10	1,850	10	1,870
3	26	3,863	27	3,932	28	3,997	30	4,057	31	4,112	32	4,162	33	4,207
4	62	6,867	65	6,991	68	7,106	70	7,212	73	7,310	76	7,399	79	7,479
5	121	10,730	126	10,923	132	11,103	137	11,269	143	11,422	148	11,561	153	11,686
6	208	15,451	218	15,729	228	15,988	237	16,228	247	16,448	256	16,647	265	16,827
7	331	21,031	347	21,409	362	21,762	377	22,088	392	22,387	407	22,659	421	22,903
8	494	27,469	517	27,963	540	28,424	563	28,849	585	29,240	607	29,595	628	29,915
9	703	34,765	736	35,391	769	35,974	802	36,513	834	37,007	865	37,456	895	37,861
10	965	42,920	1,011	43,692	1,055	44,412	1,100	45,077	1,143	45,688	1,186	46,243	1,227	46,742
11	1,284	51,933	1,345	52,868	1,405	53,738	1,464	54,544	1,522	55,282	1,579	55,954	1,634	56,558
12	1,667	61,805	1,746	62,917	1,824	63,953	1,901	64,911	1,976	65,790	2,049	66,590	2,121	67,308
13	2,119	72,535	2,220	73,840	2,319	75,056	2,416	76,180	2,512	77,212	2,606	78,151	2,697	78,994
14	2,647	84,123	2,772	85,637	2,896	87,047	3,018	88,351	3,138	89,548	3,254	90,636	3,368	91,614
15	3,255	96,570	3,410	98,308	3,562	99,927	3,712	101,424	3,859	102,798	4,003	104,047	4,142	105,169
16	3,951	109,875	4,138	111,853	4,323	113,694	4,505	115,398	4,684	116,961	4,858	118,382	5,027	119,659
17	4,739	124,038	4,963	126,271	5,185	128,350	5,404	130,273	5,618	132,038	5,827	133,642	6,030	135,084
18	5,625	139,060	5,892	141,563	6,155	143,894	6,414	146,050	6,669	148,029	6,917	149,827	7,158	151,443
19	6,616	154,941	6,929	157,730	7,239	160,327	7,544	162,729	7,843	164,933	8,135	166,937	8,417	168,738
20	7,716	171,679	8,082	174,770	8,443	177,647	8,799	180,309	9,147	182,752	9,488	184,972	9,819	186,967
21	8,932	189,276	9,356	192,683	9,774	195,856	10,186	198,791	10,589	201,484	10,983	203,932	11,367	206,132
22	10,270	207,732	10,757	211,471	11,238	214,953	11,711	218,174	12,175	221,130	12,629	223,816	13,066	226,230
23	11,735	227,046	12,292	231,133	12,841	234,939	13,382	238,459	13,912	241,689	14,430	244,625	14,934	247,264
24	13,334	247,218	13,966	251,668	14,590	255,812	15,205	259,645	15,807	263,162	16,395	266,360	16,968	269,233
25	15,071	268,249	15,785	273,077	16,491	277,574	17,185	281,733	17,866	285,550	18,531	289,020	19,178	292,136
26	16,952	290,138	17,756	295,360	18,549	300,223	19,331	304,722	20,097	308,850	20,845	312,602	21,573	315,974
27	18,985	312,885	19,885	318,518	20,774	323,762	21,649	328,613	22,506	333,065	23,344	337,111	24,159	340,748
28	21,173	336,491	22,177	342,548	23,169	348,189	24,144	353,406	25,100	358,194	26,035	362,545	26,944	366,456
29	23,524	360,956	24,639	367,453	25,740	373,504	26,824	379,100	27,887	384,235	28,925	388,904	29,935	393,099
30	26,042	386,278	27,277	393,232	28,496	399,707	29,696	405,697	30,873	411,191	32,022	416,187	33,140	420,676
31	28,734	412,460	30,096	419,884	31,442	426,798	32,766	433,193	34,064	439,061	35,332	444,395	36,566	449,189
32	31,606	439,499	33,104	447,410	34,584	454,777	36,040	461,592	37,468	467,844	38,863	473,528	40,219	478,636
33	34,662	467,397	36,306	475,810	37,928	483,645	39,526	490,892	41,091	497,541	42,621	503,586	44,109	509,018
34	37,910	496,153	39,707	505,084	41,482	513,401	43,229	521,093	44,941	528,152	46,614	534,570	48,242	540,335
35	41,354	525,768	43,315	535,234	45,251	544,045	47,156	552,198	49,025	559,677	50,849	566,477	52,625	572,587

TABLE V—B.—*Co-ordinates of curvature for each degree of longitude, &c.*—Continued.

Degrees of longitude.	Latitude 38°.		Latitude 39°.		Latitude 40°.		Latitude 41°.		Latitude 42°.		Latitude 43°.		Latitude 44°.	
	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.
°	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*
1	1	472	1	476	1	479	1	482	1	484	1	485	1	486
2	10	1,887	10	1,903	11	1,916	11	1,927	11	1,935	12	1,941	12	1,945
3	34	4,247	35	4,281	36	4,311	37	4,335	38	4,354	39	4,367	40	4,375
4	81	7,549	84	7,611	86	7,663	88	7,706	90	7,740	92	7,764	94	7,779
5	158	11,796	163	11,892	168	11,974	172	12,041	177	12,093	180	12,131	184	12,154
6	274	16,986	282	17,125	290	17,242	298	17,339	305	17,414	312	17,469	318	17,502
7	435	23,120	448	23,308	462	23,469	473	23,600	484	23,703	495	23,777	505	23,822
8	649	30,198	669	30,444	688	30,653	706	30,824	723	30,959	739	31,055	754	31,114
9	925	38,219	952	38,530	979	38,795	1,005	39,012	1,030	39,182	1,053	39,304	1,074	39,378
10	1,267	47,184	1,306	47,568	1,343	47,895	1,379	48,163	1,412	48,373	1,444	48,524	1,474	48,615
11	1,687	57,092	1,739	57,558	1,788	57,953	1,835	58,278	1,880	58,531	1,922	58,713	1,961	58,825
12	2,190	67,944	2,257	68,498	2,321	68,969	2,382	69,355	2,440	69,657	2,495	69,874	2,546	70,006
13	2,785	79,740	2,870	80,390	2,951	80,942	3,029	81,396	3,103	81,750	3,172	82,005	3,237	82,160
14	3,478	92,480	3,585	93,234	3,686	93,874	3,783	94,400	3,875	94,811	3,962	95,107	4,043	95,286
15	4,278	106,164	4,408	107,029	4,534	107,764	4,653	108,367	4,767	108,839	4,873	109,178	4,973	109,385
16	5,192	120,790	5,350	121,775	5,502	122,611	5,647	123,298	5,785	123,835	5,914	124,221	6,036	124,455
17	6,227	136,361	6,417	137,472	6,600	138,416	6,774	139,192	6,939	139,798	7,094	140,234	7,240	140,499
18	7,392	152,875	7,618	154,121	7,833	155,180	8,041	156,049	8,237	156,728	8,421	157,217	8,594	157,514
19	8,694	170,333	8,959	171,722	9,216	172,901	9,457	173,869	9,687	174,626	9,904	175,171	10,107	175,502
20	10,140	188,735	10,450	190,273	10,744	191,580	11,030	192,653	11,299	193,492	11,552	194,095	11,788	194,462
21	11,738	208,081	12,097	209,776	12,440	211,217	12,768	212,400	13,080	213,325	13,372	213,990	13,646	214,394
22	13,496	228,369	13,908	230,230	14,304	231,811	14,681	233,110	15,038	234,125	15,375	234,855	15,690	235,299
23	15,422	249,602	15,892	251,636	16,344	253,364	16,775	254,784	17,184	255,893	17,569	256,691	17,929	257,176
24	17,522	271,778	18,057	273,993	18,570	275,875	19,059	277,420	19,524	278,628	19,961	279,497	20,370	280,025
25	19,805	294,898	20,409	297,302	20,989	299,343	21,542	301,020	22,068	302,331	22,562	303,273	23,024	303,846
26	22,278	318,962	22,958	321,562	23,610	323,770	24,232	325,584	24,823	327,001	25,379	328,021	25,899	328,640
27	24,947	343,969	25,710	346,773	26,440	349,154	27,137	351,110	27,805	352,639	28,421	353,738	29,004	354,407
28	27,824	369,921	28,674	372,936	29,488	375,496	30,266	377,600	31,003	379,244	31,698	380,426	32,347	381,145
29	30,913	396,815	31,857	400,049	32,762	402,796	33,626	405,053	34,445	406,816	35,217	408,085	35,938	408,856
30	34,223	424,654	35,267	428,114	36,269	431,054	37,226	433,469	38,132	435,356	38,987	436,714	39,786	437,539
31	37,760	453,436	38,913	457,131	40,018	460,270	41,074	462,849	42,074	464,864	43,017	466,313	43,898	467,194
32	41,534	483,162	42,801	487,099	44,017	490,444	45,178	493,191	46,279	495,339	47,316	496,883	48,285	497,822
33	45,551	513,831	46,940	518,019	48,274	521,576	49,547	524,498	50,754	526,781	51,892	528,424	52,955	529,422
34	49,818	545,444	51,339	549,889	52,798	553,665	54,190	556,767	55,509	559,191	56,753	560,934	57,916	561,994
35	54,344	578,001	56,003	582,711	57,594	586,713	59,113	590,000	60,553	592,568	61,910	594,416	63,178	595,539

TABLE V—B.—*Co-ordinates of curvature for each degree of longitude, &c.*—Continued.

Degrees of longitude.	Latitude 45°.		Latitude 46°.		Latitude 47°.		Latitude 48°.		Latitude 49°.		Latitude 50°.	
	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.	X.	Y.
°	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*
1	2	486	2	486	2	485	2	484	2	482	2	479
2	12	1,946	12	1,945	12	1,941	13	1,936	13	1,927	13	1,917
3	41	4,378	41	4,376	42	4,368	42	4,355	43	4,337	43	4,313
4	96	7,784	98	7,780	99	7,765	100	7,743	102	7,710	102	7,668
5	188	12,162	191	12,155	194	12,134	196	12,098	198	12,046	200	11,981
6	324	17,513	330	17,504	335	17,473	339	17,420	343	17,347	346	17,252
7	515	23,837	523	23,824	531	23,782	538	23,711	544	23,611	549	23,483
8	768	31,135	781	31,118	793	31,062	803	30,969	812	30,839	820	30,671
9	1,094	39,405	1,113	39,383	1,129	39,313	1,144	39,196	1,157	39,030	1,168	38,817
10	1,501	48,648	1,526	48,621	1,549	48,535	1,569	48,390	1,587	48,186	1,602	47,923
11	1,998	58,864	2,031	58,831	2,061	58,727	2,088	58,552	2,112	58,305	2,132	57,987
12	2,594	70,053	2,637	70,014	2,676	69,890	2,711	69,681	2,742	69,387	2,768	69,009
13	3,298	82,215	3,353	82,170	3,403	82,024	3,447	81,779	3,486	81,434	3,519	80,989
14	4,119	95,350	4,188	95,298	4,250	95,129	4,306	94,844	4,354	94,444	4,395	93,929
15	5,066	109,458	5,150	109,397	5,227	109,204	5,296	108,877	5,355	108,418	5,406	107,826
16	6,148	124,539	6,251	124,470	6,344	124,250	6,427	123,878	6,499	123,355	6,561	122,682
17	7,374	140,592	7,497	140,515	7,610	140,266	7,709	139,847	7,796	139,257	7,870	138,497
18	8,753	157,619	8,900	157,532	9,033	157,252	9,152	156,783	9,254	156,122	9,342	155,270
19	10,295	175,619	10,467	175,522	10,624	175,212	10,762	174,688	10,884	173,950	10,987	173,001
20	12,008	194,592	12,209	194,484	12,391	194,140	12,553	193,559	12,694	192,743	12,815	191,691
21	13,900	214,533	14,133	214,419	14,344	214,040	14,531	213,399	14,695	212,499	14,834	211,340
22	15,982	235,456	16,250	235,326	16,492	234,910	16,708	234,207	16,896	233,219	17,056	231,947
23	18,262	257,347	18,568	257,206	18,844	256,750	19,091	255,982	19,306	254,902	19,489	253,511
24	20,749	280,212	21,097	280,058	21,411	279,562	21,691	278,726	21,936	277,550	22,144	276,035
25	23,452	304,049	23,845	303,882	24,200	303,314	24,517	302,437	24,793	301,161	25,028	299,517
26	26,381	328,860	26,822	328,679	27,222	328,097	27,578	327,116	27,889	325,735	28,153	323,958
27	29,543	354,643	30,038	354,448	30,485	353,821	30,884	352,762	31,232	351,274	31,529	349,357
28	32,949	381,400	33,500	381,190	34,000	380,515	34,444	379,377	34,833	377,776	35,163	375,714
29	36,607	409,129	37,220	408,904	37,774	408,180	38,268	406,959	38,700	405,242	39,067	403,030
30	40,526	437,831	41,204	437,590	41,818	436,816	42,365	435,509	42,843	433,671	43,249	431,305
31	44,715	467,506	45,463	467,249	46,141	466,422	46,744	465,027	47,272	463,064	47,720	460,538
32	49,183	498,155	50,006	497,880	50,752	496,999	51,416	495,512	51,995	493,422	52,488	490,729
33	53,940	529,776	54,843	529,484	55,660	528,547	56,388	526,966	57,024	524,742	57,565	521,879
34	58,993	562,370	59,981	562,060	60,875	561,065	61,671	559,387	62,367	557,026	62,958	553,987
35	64,354	595,937	65,431	595,609	66,405	594,555	67,274	592,776	68,033	590,275	68,678	587,054

TABLE VI.—*Projection Tables, giving latitude and longitude arcs, and co-ordinates of curvature, from latitude 24° to latitude 50°.*

LATITUDE 24° 00′.

Min.	Length in metres of arcs parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	197.8	226.1	254.3	282.6	565.2	847.8	1130.4	1413.1	1695.66
1	7.8	6.1	4.3	2.6	5.1	7.7	0.3	2.9	5.44
2	7.8	6.0	4.3	2.5	5.1	7.6	0.2	2.7	5.23
3	7.8	6.0	4.3	2.5	5.0	7.5	0.0	2.5	5.01
4	7.7	6.0	4.2	2.5	4.9	7.4	1129.9	2.3	4.79
5	7.7	5.9	4.2	2.4	4.9	7.3	9.7	2.1	4.57
6	197.7	225.9	254.2	282.4	564.8	847.2	1129.6	1412.0	1694.35
7	7.6	5.9	4.1	2.4	4.7	7.1	9.4	1.8	4.13
8	7.6	5.9	4.1	2.3	4.6	7.0	9.3	1.6	3.91
9	7.6	5.8	4.1	2.3	4.6	6.8	9.1	1.4	3.69
10	7.6	5.8	4.0	2.2	4.5	6.7	9.0	1.2	3.47
11	197.5	225.8	254.0	282.2	564.4	846.6	1128.8	1411.0	1693.25
12	7.5	5.7	4.0	2.2	4.3	6.5	8.7	10.9	3.03
13	7.5	5.7	3.9	2.1	4.3	6.4	8.5	10.7	2.81
14	7.5	5.7	3.9	2.1	4.2	6.3	8.4	10.5	2.59
15	7.4	5.6	3.9	2.1	4.1	6.2	8.2	10.3	2.37
16	197.4	225.6	253.8	282.0	564.0	846.1	1128.1	1410.1	1692.15
17	7.4	5.6	3.8	2.0	4.0	6.0	8.0	1409.9	1.93
18	7.4	5.6	3.8	2.0	3.9	5.9	7.8	9.8	1.71
19	7.3	5.5	3.7	1.9	3.8	5.7	7.7	9.6	1.49
20	7.3	5.5	3.7	1.9	3.8	5.6	7.5	9.4	1.27
21	197.3	225.5	253.7	281.8	563.7	845.5	1127.4	1409.2	1691.05
22	7.3	5.4	3.6	1.8	3.6	5.4	7.2	9.0	0.82
23	7.2	5.4	3.6	1.8	3.5	5.3	7.1	8.8	0.60
24	7.2	5.4	3.6	1.7	3.5	5.2	6.9	8.7	0.38
25	7.2	5.4	3.5	1.7	3.4	5.1	6.8	8.5	0.16
26	197.2	225.3	253.5	281.7	563.3	845.0	1126.6	1408.3	1689.94
27	7.1	5.3	3.5	1.6	3.2	4.9	6.5	8.1	9.71
28	7.1	5.3	3.4	1.6	3.2	4.7	6.3	7.9	9.49
29	7.1	5.2	3.4	1.6	3.1	4.6	6.2	7.7	9.27
30	7.1	5.2	3.4	1.5	3.0	4.5	6.0	7.5	9.05

Meridional arcs.	
1″	30.8
2	61.5
3	92.3
4	123.1
5	153.8
6	184.6
7	215.3
8	246.1
9	276.9
10	307.6
20	615.3
30	922.9
40	1230.5
50	1538.2
1′ 00	1845.8
2	3691.6
3	5537.4
4	7383.1
5	9228.9
6	11074.7
7	12920.5
8	14766.3
9	16612.1
10	18457.8
11	20303.6
12	22149.4

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc. par.	Y.
1′	—.0	.1
2	.0	.4
3	.0	.9
4	.0	1.6
5	.0	2.5
6	.0	3.6
7	.0	4.9
8	.0	6.4
9	.0	8.1
10	.0	10.0
15	.0	22.6
20	.0	40.1
25	.0	62.7
30	.1	90.3
35	.1	122.9
40	.2	160.5
45	.3	203.1
50	.4	256.8
55	.5	303.5
1° 00	.6	361.1
1 10	1.0	491.5
1 20	1.5	642.0
1 30	2.2	812.5
1 40	3.0	1003.1
1 50	3.9	1213.8
2 00	5.1	1444.4

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 24° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.) 7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	197.1	225.2	253.4	281.5	563.0	844.5	1126.0	1407.5	1689.05
31	7.0	5.2	3.3	1.5	2.9	4.4	5.9	7.4	8.82
32	7.0	5.1	3.3	1.4	2.9	4.3	5.7	7.2	8.60
33	7.0	5.1	3.3	1.4	2.8	4.2	5.6	7.0	8.38
34	7.0	5.1	3.2	1.4	2.7	4.1	5.4	6.8	8.16
35	196.9	5.1	3.2	1.3	2.6	4.0	5.3	6.6	7.93
36	196.9	225.0	253.2	281.3	562.6	843.9	1125.1	1406.4	1687.71
37	6.9	5.0	3.1	1.2	2.5	3.7	5.0	6.2	7.49
38	6.8	5.0	3.1	1.2	2.4	3.6	4.8	6.0	7.26
39	6.8	4.9	3.1	1.2	2.3	3.5	4.7	5.9	7.04
40	6.8	4.9	3.0	1.1	2.3	3.4	4.5	5.7	6.81
41	196.8	224.9	253.0	281.1	562.2	843.3	1124.4	1405.5	1686.59
42	6.7	4.8	3.0	1.1	2.1	3.2	4.2	5.3	6.36
43	6.7	4.8	2.9	1.0	2.0	3.1	4.1	5.1	6.14
44	6.7	4.8	2.9	1.0	2.0	3.0	4.0	4.9	5.92
45	6.7	4.8	2.9	0.9	1.9	2.8	3.8	4.7	5.69
46	196.6	224.7	252.8	280.9	561.8	842.7	1123.6	1404.6	1885.47
47	6.6	4.7	2.8	0.9	1.7	2.6	3.5	4.4	5.24
48	6.6	4.7	2.8	0.8	1.7	2.5	3.4	4.2	5.02
49	6.6	4.6	2.7	0.8	1.6	2.4	3.2	4.0	4.79
50	6.5	4.6	2.7	0.8	1.5	2.3	3.0	3.8	4.57
51	196.5	224.6	252.7	280.7	561.4	842.2	1122.9	1403.6	1684.34
52	6.5	4.5	2.6	0.7	1.4	2.1	2.8	3.4	4.12
53	6.5	4.5	2.6	0.6	1.3	1.9	2.6	3.2	3.89
54	6.4	4.5	2.5	0.6	1.2	1.8	2.4	3.0	3.66
55	6.4	4.5	2.5	0.6	1.1	1.7	2.3	2.9	3.44
56	196.4	224.4	252.5	280.5	561.1	841.6	1122.1	1402.7	16 3.21
57	6.3	4.4	2.4	0.5	1.0	1.5	2.0	2.5	2.99
58	6.3	4.4	2.4	0.5	0.9	1.4	1.8	2.3	2.76
59	6.3	4.3	2.4	0.4	0 8	1.3	1.7	2.1	2.53
60	6.3	4.3	2.3	0.4	0.8	1.2	1.5	1.9	2.31

Meridional arcs.	
1″	30.8
2	61.5
3	92.3
4	123.1
5	153.8
6	184.6
7	215.4
8	246.1
9	276.9
10	307.6
20	615.3
30	922.9
40	1230.6
50	1538.3
1′ 00	1845.9
2	3691.8
3	5537.7
4	7383.7
5	9229.5
6	11075.4
7	12921.3
8	14767.2
9	16613.1
10	18459.0
11	20304.9
12	22150.9

Co-ordinates of curvature. Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.4
3	.0	.9
4	.0	1.6
5	.0	2.5
6	.0	3.7
7	.0	5.0
8	.0	6.5
9	.0	8.3
10	.0	10.2
15	.0	22.9
20	.0	40.7
25	.0	63.7
30	.1	91.7
35	.1	124.8
40	.2	163.0
45	.3	206.3
50	.4	254.7
55	.5	308.2
1° 00	.7	366.7
1 10	1.1	499.2
1 20	1.6	652.0
1 30	2.2	825.2
1 40	3.1	1018.7
1 50	4.1	1232.7
2 00	5.3	1467.0

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 25° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	196.3	224.3	252.3	280.4	560.8	841.2	1121.5	1401.9	1682.31
1	6.2	4.3	2.3	0.3	0.7	1.0	1.4	1.7	2.08
2	6.2	4.2	2.3	0.3	0.6	0.9	1.2	1.5	1.85
3	6.2	4.2	2.2	0.3	0.5	0.8	1.1	1.4	1.62
4	6.2	4.2	2.2	0.2	0.5	0.7	0.9	1.2	1.39
5	6.1	4.2	2.2	0.2	0.4	0.6	0.8	1.0	1.17
6	196.1	224.1	252.1	280.2	560.3	840.5	1120.6	1400.8	1680.94
7	6.1	4.1	2.1	0.1	0.2	0.4	0.5	0.6	0.71
8	6.1	4.1	2.1	0.1	0.2	0.2	0.3	0.4	0.48
9	6.0	4.0	2.0	0.0	0.1	0.1	0.2	0.2	0.26
10	6.0	4.0	2.0	0.0	0.0	0.0	0.0	0.0	0.03
11	196.0	224.0	252.0	280.0	559.9	839.9	1119.9	1399.8	1679.80
12	5.9	3.9	1.9	9.9	9.9	9.8	9.7	9.6	9.57
13	5.9	3.9	1.9	9.9	9.8	9.7	9.6	9.5	9.34
14	5.9	3.9	1.9	9.9	9.7	9.5	9.4	9.3	9.11
15	5.9	3.9	1.8	9.8	9.6	9.4	9.3	9.1	8.88
16	195.8	223.8	251.8	279.8	559.5	839.3	1119.1	1398.9	1678.65
17	5.8	3.8	1.8	9.7	9.5	9.2	9.0	8.7	8.42
18	5.8	3.8	1.7	9.7	9.4	9.1	8.8	8.5	8.20
19	5.8	3.7	1.7	9.7	9.3	9.0	8.6	8.3	7.97
20	5.7	3.7	1.7	9.6	9.2	8.9	8.5	8.1	7.74
21	195.7	223.7	251.6	279.6	559.2	838.8	1118.3	1397.9	1677.51
22	5.7	3.6	1.6	9.5	9.1	8.6	8.2	7.7	7.28
23	5.7	3.6	1.6	9.5	9.0	8.5	8.0	7.5	7.05
24	5.6	3.6	1.5	9.5	8.9	8.4	7.9	7.3	6.81
25	5.6	3.5	1.5	9.4	8.9	8.3	7.7	7.2	6.59
26	195.6	223.5	251.5	279.4	558.8	838.2	1117.6	1397.0	1676.36
27	5.5	3.5	1.4	9.4	8.7	8.1	7.4	6.8	6.12
28	5.5	3.5	1.4	9.3	8.6	7.9	7.3	6.6	5.89
29	5.5	3.4	1.3	9.3	8.6	7.8	7.1	6.4	5.66
30	5.5	3.4	1.3	9.2	8.5	7.7	6.9	6.2	5.43

Meridional arcs.	
1″	30.8
2	61.5
3	92.3
4	123.1
5	153.8
6	184.6
7	215.4
8	246.1
9	276.9
10	307.7
20	615.3
30	923.0
40	1230.7
50	1538.4
1′ 00	1846.0
2	3692.1
3	5538.1
4	7384.1
5	9230.1
6	11076.2
7	12922.2
8	14768.2
9	16614.2
10	18460.3
11	20306.3
12	22152.3

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.4
3	.0	.9
4	.0	1.6
5	.0	2.6
6	.0	3.7
7	.0	5.1
8	.0	6.6
9	.0	8.4
10	.0	10.3
15	.0	23.3
20	.0	41.4
25	.0	64.6
30	.1	93.1
35	.1	126.7
40	.2	165.5
45	.3	209.4
50	.4	258.5
55	.5	312.8
1° 00	.7	372.3
1 10	1.1	506.7
1 20	1.6	661.8
1 30	2.3	837.6
1 40	3.2	1034.1
1 50	4.2	1251.2
2 00	5.5	1489.1

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 25° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	195. 5	223. 4	251. 3	279. 2	558. 5	837. 7	1116. 9	1396. 2	1675. 43
31	5. 4	3. 4	1. 3	9. 2	8. 4	7. 6	6. 8	6. 0	5. 20
32	5. 4	3. 3	1. 2	9. 2	8. 3	7. 5	6. 6	5. 8	4. 97
33	5. 4	3. 3	1. 2	9. 1	8. 2	7. 4	6. 5	5. 6	4. 74
34	5. 4	3. 3	1. 2	9. 1	8. 2	7. 3	6. 3	5. 4	4. 51
35	5. 3	3. 2	1. 1	9. 0	8. 1	7. 1	6. 2	5. 2	4. 27
36	195. 3	223. 2	251. 1	279. 0	558. 0	837. 0	1116. 0	1395. 0	1674. 04
37	5. 3	3. 2	1. 1	9. 0	7. 9	6. 9	5. 9	4. 8	3. 81
38	5. 3	3. 1	1. 0	8. 9	7. 9	6. 8	5. 7	4. 6	3. 58
39	5. 2	3. 1	1. 0	8. 9	7. 8	6. 7	5. 6	4. 4	3. 34
40	5. 2	3. 1	1. 0	8. 8	7. 7	6. 6	5. 4	4. 3	3. 11
41	195. 2	223. 1	250. 9	278. 8	557. 6	836. 4	1115. 3	1394. 1	1672. 88
42	5. 1	3. 0	0. 9	8. 8	7. 5	6. 3	5. 1	3. 9	2. 65
43	5. 1	3. 0	0. 9	8. 7	7. 5	6. 2	4. 9	3. 7	2. 41
44	5. 1	3. 0	0. 8	8. 7	7. 4	6. 1	4. 8	3. 5	2. 18
45	5. 1	2. 9	0. 8	8. 7	7. 3	6. 0	4. 6	3. 3	1. 95
46	195. 0	222. 9	250. 8	278. 6	557. 2	835. 9	1114. 5	1393. 1	1671. 71
47	5. 0	2. 9	0. 7	8. 6	7. 2	5. 7	4. 3	2. 9	1. 48
48	5. 0	2. 8	0. 7	8. 5	7. 1	5. 6	4. 2	2. 7	1. 25
49	5. 0	2. 8	0. 7	8. 5	7. 0	5. 5	4. 0	2. 5	1. 01
50	4. 9	2. 8	0. 6	8. 5	6. 9	5. 4	3. 9	2. 3	0. 78
51	194. 9	222. 7	250. 6	278. 4	556. 8	835. 3	1113. 7	1392. 1	1670. 55
52	4. 9	2. 7	0. 6	8. 4	6. 8	5. 2	3. 5	1. 9	70. 32
53	4. 8	2. 7	0. 5	8. 3	6. 7	5. 0	3. 4	1. 7	70. 08
54	4. 8	2. 6	0. 5	8. 3	6. 6	4. 9	3. 2	1. 6	69. 84
55	4. 8	2. 6	0. 4	8. 3	6. 5	4. 8	3. 1	1. 4	69. 61
56	194. 8	222. 6	250. 4	278. 2	556. 5	834. 7	1112. 9	1391. 2	1669. 37
57	4. 7	2. 6	0. 4	8. 2	6. 4	4. 6	2. 8	1. 0	9. 14
58	4. 7	2. 5	0. 3	8. 1	6. 3	4. 5	2. 6	0. 8	8. 90
59	4. 7	2. 5	0. 3	8. 1	6. 2	4. 3	2. 5	0. 6	8. 67
60	1. 6	2. 5	0. 3	8. 1	6. 1	4. 2	2. 3	0. 4	8. 43

Meridional arcs.	
1′	30. 8
2	61. 5
3	92. 3
4	123. 1
5	153. 8
6	184. 6
7	215. 4
8	246. 2
9	276. 9
10	307. 7
20	615. 4
30	923. 1
40	1230. 8
50	1538. 5
1′ 00	1846. 2
2	3692. 3
3	5538. 5
4	7384. 6
5	9230. 8
6	11076. 9
7	12923. 1
8	14769. 2
9	16615. 4
10	18461. 6
11	20307. 7
12	22153. 9

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—. 0	. 1
2	. 0	. 4
3	. 0	. 9
4	. 0	1. 7
5	. 0	2. 6
6	. 0	3. 8
7	. 0	5. 1
8	. 0	6. 7
9	. 0	8. 5
10	. 0	10. 5
15	. 0	23. 6
20	. 0	42. 0
25	. 1	65. 6
30	. 1	94. 4
35	. 1	128. 5
40	. 2	168. 0
45	. 3	212. 4
50	. 4	262. 3
55	. 5	317. 3
1° 00	. 7	377. 7
1 10	1. 1	514. 0
1 20	1. 7	671. 4
1 30	2. 4	849. 7
1 40	3. 3	1049. 1
1 50	4. 4	1269. 4
2 00	5. 7	1510. 6

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 26° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	194.6	222.5	250.3	278.1	256.1	834.2	1112.3	1390.4	1668.43
1	4.6	2.4	0.2	8.0	6.1	4.1	2.1	0.2	8.20
2	4.6	2.4	0.2	8.0	6.0	4.0	2.0	0.0	7.96
3	4.6	2.4	0.2	8.0	5.9	3.9	1.8	1389.8	7.72
4	4.5	2.3	0.1	7.9	5.8	3.7	1.7	9.6	7.49
5	4.5	2.3	0.1	7.9	5.7	3.6	1.5	9.4	7.25
6	194.5	222.3	250.1	277.8	555.7	833.5	1111.3	1389.2	1667.02
7	4.5	2.2	0.0	7.8	5.6	3.4	1.2	9.0	6.78
8	4.4	2.2	0.0	7.8	5.5	3.3	1.0	8.8	6.54
9	4.4	2.2	249.9	7.7	5.4	3.2	0.9	8.6	6.31
10	4.4	2.1	9.9	7.7	5.4	3.0	0.7	8.4	6.07
11	194.3	222.1	249.9	277.6	555.3	832.9	1110.6	1388.2	1665.83
12	4.3	2.1	9.8	7.6	5.2	2.8	0.4	8.0	5.60
13	4.3	2.0	9.8	7.6	5.1	2.7	0.2	7.8	5.36
14	4.3	2.0	9.8	7.5	5.0	2.6	0.1	7.6	5.12
15	4.2	2.0	9.7	7.5	5.0	2.4	1109.9	7.4	4.88
16	194.2	222.0	249.7	277.4	554.9	832.3	1109.8	1387.2	1664.65
17	4.2	1.9	9.7	7.4	4.8	2.2	9.6	7.0	4.41
18	4.2	1.9	9.6	7.4	4.7	2.1	9.4	6.8	4.17
19	4.1	1.9	9.6	7.3	4.6	2.0	9.3	6.6	3.93
20	4.1	1.8	9.5	7.3	4.6	1.8	9.1	6.4	3.69
21	194.1	221.8	249.5	277.2	554.5	831.7	1109.0	1386.2	1663.46
22	4.0	1.8	9.5	7.2	4.4	1.6	8.8	6.0	3.22
23	4.0	1.7	9.4	7.2	4.3	1.5	8.6	5.8	2.98
24	4.0	1.7	9.4	7.1	4.2	1.4	8.5	5.6	2.74
25	4.0	1.7	9.4	7.1	4.2	1.2	8.3	5.4	2.50
26	193.9	221.6	249.3	277.0	554.1	831.1	1108.2	1385.2	1662.26
27	3.9	1.6	9.3	7.0	4.0	1.0	8.0	5.0	2.02
28	3.9	1.6	9.3	7.0	3.9	0.9	7.9	4.8	1.78
29	3.9	1.5	9.2	6.9	3.8	0.8	7.7	4.6	1.55
30	3.8	1.5	9.2	6.9	3.8	0.7	7.5	4.4	1.31

Meridional arcs.	
1″	30.8
2	61.5
3	92.3
4	123.1
5	153.8
6	184.6
7	215.4
8	246.2
9	276.9
10	307.7
20	615.4
30	923.1
40	1230.9
50	1538.6
1′ 00	1846.3
2	3692.6
3	5538.8
4	7385.1
5	9231.4
6	11077.7
7	12924.0
8	14770.2
9	16616.5
10	18462.8
11	20309.1
12	22155.4

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.4
3	.0	1.0
4	0	1.7
5	.0	2.7
6	.0	3.8
7	.0	5.2
8	.0	6.8
9	.0	8.6
10	.0	10.6
15	.0	23.9
20	.0	42.6
25	.1	66.5
30	.1	95.7
35	.1	130.3
40	.2	170.2
45	.3	215.4
50	.4	265.9
55	.6	321.8
1° 00	.7	383.0
1 10	1.2	521.2
1 20	1.7	680.8
1 30	2.5	861.6
1 40	3.4	1063.7
1 50	4.5	1287.1
2 00	5.9	1531.8

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 26° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)									Meridional arcs.		Co-ordinates of curvature.		
	7″	8″	9″	10″	20″	30″	40″	50″	60″			Minutes of longitude.	X. Arc par.	Y.
30′	193.8	221.5	249.2	276.9	553.8	830.7	1107.5	1384.4	1661.31	1″	30.8	1′	—.0	.1
31	3.8	1.5	9.2	6.8	3.7	0.5	7.4	4.2	1.07	2	61.5	2	.0	.4
32	3.8	1.4	9.1	6.8	3.6	0.4	7.2	4.0	0.83	3	92.3	3	.0	1.0
33	3.7	1.4	9.1	6.8	3.5	0.3	7.1	3.8	0.59	4	123.1	4	.0	1.7
34	3.7	1.4	9.1	6.7	3.4	0.2	6.9	3.6	0.35					
35	3.7	1.3	9.0	6.7	3.4	0.1	6.7	3.4	0.11	5	153.9	5	.0	2.7
										3	184.6	6	.0	3.9
36	193.7	221.3	249.0	276.6	553.3	829.9	1106.6	1383.2	1659.87	7	215.4	7	.0	5.3
37	3.6	1.3	8.9	6.6	3.2	9.8	6.4	3.0	9.63	8	246.2	8	.0	6.9
38	3.6	1.3	8.9	6.6	3.1	9.7	6.3	2.8	9.38	9	277.0	9	.0	8.7
39	3.6	1.2	8.9	6.5	3.0	9.6	6.1	2.6	9.14					
40	3.5	1.2	8.8	6.5	3.0	9.5	5.9	2.4	8.90	10	307.7	10	.0	10.8
										20	615.5	15	.0	24.3
41	193.5	221.2	248.8	276.4	552.9	829.3	1105.8	1382.2	1658.66	30	923.2	20	.0	43.1
42	3.5	1.1	8.8	6.4	2.8	9.2	5.6	2.0	8.42	40	1230.9	25	.1	67.4
43	3.5	1.1	8.7	6.4	2.7	9.1	5.5	1.8	8.18	50	1538.7	30	.1	97.0
44	3.4	1.1	8.7	6.3	2.6	9.0	5.3	1.6	7.94					
45	3.4	1.0	8.7	6.3	2.6	8.8	5.1	1.4	7.70	1′ 00	1846.4	35	.2	132.1
										2	3692.8	40	.2	172.5
46	193.4	221.0	248.6	276.2	552.5	828.7	1105.0	1331.2	1657.45	3	5539.2	45	.3	218.3
47	3.3	1.0	8.6	6.2	2.4	8.6	4.8	1.0	7.21	4	7385.6	50	.4	269.5
48	3.3	0.9	8.5	6.2	2.3	8.5	4.6	0.8	6.97	5	9232.0	55	.6	326.1
49	3.3	0.9	8.5	6.1	2.2	8.4	4.5	0.6	6.73	6	11078.4			
50	3.2	0.9	8.5	6.1	2.2	8.2	4.3	0.4	6.49			1° 00	.8	388.1
										7	12924.8	1 10	1.2	528.3
51	193.2	220.8	248.4	276.0	552.1	828.1	1104.2	1380.2	1656.24	8	14771.3	1 20	1.8	690.0
52	3.2	0.8	8.4	6.0	2.0	8.0	4.0	0.0	6.00	9	16617.7	1 30	2.5	873.3
53	3.2	0.8	8.4	6.0	1.9	7.9	3.8	1379.8	5.76	10	18464.1	1 40	3.5	1078.1
54	3.1	0.7	8.3	5.9	1.8	7.7	3.7	9.6	5.51	11	20310.5	1 50	4.6	1304.6
55	3.1	0.7	8.3	5.9	1.8	7.6	3.5	9.4	5.27	12	22156.9	2 00	6.0	1552.5
56	193.1	220.7	248.3	275.8	551.7	827.5	1103.4	1379.2	1655.03					
57	3.1	0.6	8.2	5.8	1.6	7.4	3.2	9.0	4.78					
58	3.0	0.6	8.2	5.8	1.5	7.3	3.0	8.8	4.54					
59	3.0	0.6	8.1	5.7	1.4	7.2	2.9	8.6	4.30					
60	3.0	0.5	8.1	5.7	1.3	7.0	2.7	8.4	4.05					

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 27° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)									Meridional arcs.		Co-ordinates of curvature.		
	7″	8″	9″	10″	20″	30″	40″	50″	60″			Minutes of longitude.	X. Arc par.	Y.
0′	193.0	220.5	248.1	275.7	551.3	827.0	1102.7	1378.4	1654.05	1″	30.8	1′	—.0	.1
1	2.9	0.5	8.1	5.6	1.3	6.9	2.5	8.2	3.81	2	61.5	2	.0	.4
2	2.9	0.5	8.0	5.6	1.2	6.8	2.4	8.0	3.57	3	92.3	3	.0	1.0
3	2.9	0.4	8.0	5.6	1.1	6.7	2.2	7.8	3.32	4	123.1	4	.0	1.7
4	2.9	0.4	8.0	5.5	1.0	6.5	2.1	7.6	3.08					
5	2.8	0.4	7.9	5.5	0 9	6.4	1.9	7.4	2.83	5	153.9	5	.0	2.7
										6	184.7	6	.0	3.9
6	192.8	220.3	247.9	275.4	550.9	826.3	1101.7	1377.2	1652.59	7	215.4	7	.0	5.4
7	2.8	0.3	7.9	5.4	0.8	6.2	1.6	7.0	2.34	8	246.2	8	.0	7.0
8	2.7	0.3	7.8	5.4	0.7	6.0	1.4	6.7	2.10	9	277.0	9	.0	8.8
9	2.7	0.2	7.8	5.3	0.6	5.9	1.2	6.5	1.86					
10	2.7	0.2	7.7	5.3	0.5	5.8	1.1	6.3	1.61	10	307.8	10	.0	10.9
										20	615.5	15	.0	24.6
11	192.7	220.2	247.7	275.2	550.5	825.7	1100.9	1376.1	1651.36	30	923.3	20	.0	43.7
12	2.6	0.1	7.7	5.2	0.4	5.6	0.8	5.9	1.12	40	1231.0	25	.1	68.3
13	2.6	0.1	7.6	5.1	0.3	5.4	0.6	5.7	0.87	50	1538.8	30	.1	98.3
14	2.6	0.1	7.6	5.1	0.2	5.3	0.4	5.5	0.63					
15	2.5	0.1	7.6	5.1	0.1	5.2	0.3	5.3	0.38	1′ 00	1846.5	35	.2	133.8
										2	3693.1	40	.2	174.7
16	192.5	220.0	247.5	275.0	550.0	825.1	1100.1	1375.1	1650.13	3	5539.6	45	.3	221.2
17	2.5	0.0	7.5	5.0	0.0	4.9	1099.9	4.9	49.89	4	7386.2	50	.5	273.0
18	2.5	0.0	7.4	4.9	549.9	4.8	9.8	4.7	49.64	5	9232.7	55	.6	330.4
19	2.4	219.9	7.4	4.9	9.8	4.7	9.6	4.5	49.39	6	11079.2			
20	2.4	9.9	7.4	4.9	9.7	4.6	9.4	4.3	49.15			1° 00	.8	393.2
										7	12925.8	1 10	1.2	535.2
21	192.4	219.9	247.3	274.8	549.6	824.5	1099.3	1374.1	1648.90	8	14772.3	1 20	1.8	699.0
22	2.3	9.8	7.3	4.8	9.5	4.3	9.1	3.9	8.65	9	16618.8	1 30	2.6	884.6
23	2.3	9.8	7.3	4.7	9.5	4.2	8.9	3.7	8.41	10	18465.4	1 40	3.6	1092.0
24	2.3	9.8	7.2	4.7	9.4	4.1	8.8	3.5	8.16	11	20311.9	1 50	4.8	1321.5
25	2.3	9.7	7.2	4.7	9.3	4.0	8.6	3.3	7.91	12	22158.4	2 00	6.2	1572.8
26	192.2	219.7	247.1	274.6	549.2	823.8	1098.4	1373.1	1647.67					
27	2.2	9.7	7.1	4.6	9.1	3.7	8.3	2.8	7.42					
28	2.2	9.6	7.1	4.5	9.1	3.6	8.1	2.6	7.17					
29	2.1	9.6	7.0	4.5	9.0	3.5	8.0	2.4	6.92					
30	2.1	9.6	7.0	4.4	8.9	3.3	7.8	2.2	6.68					

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 27° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)									Meridional arcs.		Co-ordinates of curvature.		
	7″	8″	9″	10″	20″	30″	40″	50″	60″			Minutes of longitude.	X. Arc par.	Y.
30′	192.1	219.6	247.0	274.4	548.9	823.3	1097.8	1372.2	1646.68	1″	30.8	1′	—.0	.1
31	2.1	9.5	7.0	4.4	8.8	3.2	7.6	2.0	6.43	2	61.6	2	.0	.4
32	2.1	9.5	6.9	4.4	8.7	3.1	7.5	1.8	6.18	3	92.3	3	.0	1.0
33	2.0	9.5	6.9	4.3	8.6	3.0	7.3	1.6	5.93	4	123.1	4	.0	1.8
34	2.0	9.4	6.9	4.3	8.6	2.8	7.1	1.4	5.68					
35	2.0	9.4	6.8	4.2	8.5	2.7	6.9	1.2	5.43	5	153.9	5	.0	2.8
										6	184.7	6	.0	4.0
36	191.9	219.4	246.8	274.2	548.4	822.6	1096.8	1371.0	1645.18	7	215.4	7	.0	5.4
37	1.9	9.3	6.7	4.2	8.3	2.5	6.6	0.8	4.94	8	246.2	8	.0	7.1
38	1.9	9.3	6.7	4.1	8.2	2.3	6.5	0.6	4.69	9	277.0	9	.0	9.0
39	1.9	9.3	6.7	4.1	8.1	2.2	6.3	0.4	4.44					
40	1.8	9.2	6.6	4.0	8.1	2.1	6.1	0.2	4.19	10	307.8	10	.0	11.1
										20	615.5	15	.0	24.9
41	191.8	219.2	246.6	274.0	548.0	822.0	1096.0	1370.0	1643.94	30	923.3	20	.0	44.2
42	1.8	9.2	6.6	3.9	7.9	1.8	5.8	69.7	3.69	40	1231.1	25	.1	69.1
43	1.7	9.1	6.5	3.9	7.8	1.7	5.6	9.5	3.44	50	1538.9	30	.1	99.5
44	1.7	9.1	6.5	3.9	7.7	1.6	5.5	9.3	3.19					
45	1.7	9.1	6.4	3.8	7.6	1.5	5.3	9.1	2.94	1′ 00	1846.7	35	.2	135.5
										2	3693.3	40	.2	176.9
46	191.6	219.0	246.4	273.8	547.6	821.3	1095.1	1368.9	1642.69	3	5540.0	45	.3	223.9
47	1.6	9.0	6.4	3.7	7.5	1.2	5.0	8.7	2.44	4	7386.7	50	.5	276.5
48	1.6	9.0	6.3	3.7	7.4	1.1	4.8	8.5	2.19	5	9233.3	55	.6	334.5
49	1.6	8.9	6.3	3.7	7.3	1.0	4.6	8.3	1.94	6	11080.0			
50	1.5	8.9	6.3	3.6	7.2	0.8	4.5	8.1	1.69			1° 00	.8	398.1
										7	12926.7	1 10	1.3	541.9
51	191.5	218.9	246.2	273.6	547.1	820.7	1094.3	1367.9	1641.44	8	14773.3	1 20	1.9	707.8
52	1.5	8.8	6.2	3.5	7.1	0.6	4.1	7.6	1.18	9	16620.0	1 30	2.7	895.8
53	1.4	8.8	6.1	3.5	7.0	0.5	4.0	7.4	0.93	10	18466.7	1 40	3.7	1105.9
54	1.4	8.8	6.1	3.4	6.9	0.3	3.8	7.2	0.68	11	20313.3	1 50	4.9	1338.1
55	1.4	8.7	6.1	3.4	6.8	0.2	3.6	7.0	0.43	12	22160.0	2 00	6.4	1592.5
56	191.4	218.7	246.0	273.4	546.7	820.1	1093.5	1366.8	1640.18					
57	1.3	8.7	6.0	3.3	6.6	820.0	3.3	6.6	39.93					
58	1.3	8.6	6.0	3.3	6.6	819.8	3.1	6.4	39.68					
59	1.3	8.6	5.9	3.2	6.5	819.7	3.0	6.2	39.42					
60	1.2	8.6	5.9	3.2	6.4	819.6	2.8	6.0	39.17					

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 28° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	191.2	218.6	245.9	273.2	546.4	819.6	1092.8	1366.0	1639.17
1	1.2	8.5	5.8	3.2	6.3	9.5	2.6	5.8	8.92
2	1.2	8.5	5.8	3.1	6.2	9.3	2.5	5.6	8.67
3	1.1	8.5	5.8	3.1	6.1	9.2	2.3	5.3	8.41
4	1.1	8.4	5.7	3.0	6.1	9.1	2.1	5.1	8.16
5	1.1	8.4	5.7	3.0	6.0	9.0	1.9	4.9	7.91
6	191.1	218.4	245.6	272.9	545.9	818.8	1091.8	1364.7	1637.65
7	1.0	8.3	5.6	2.9	5.8	8.7	1.6	4.5	7.40
8	1.0	8.3	5.6	2.9	5.7	8.6	1.4	4.3	7.15
9	1.0	8.3	5.5	2.8	5.6	8.5	1.3	4.1	6.90
10	0.9	8.2	5.5	2.8	5.5	8.3	1.1	3.9	6.64
11	190.9	218.2	245.5	272.7	545.5	818.2	1090.9	1363.7	1636.39
12	0.9	8.2	5.4	2.7	5.4	8.1	0.8	3.4	6.13
13	0.9	8.1	5.4	2.6	5.3	7.9	0.6	3.2	5.88
14	0.8	8.1	5.3	2.6	5.2	7.8	0.4	3.0	5.63
15	0.8	8.0	5.3	2.6	5.1	7.7	0.2	2.8	5.37
16	190.8	218.0	245.3	272.5	545.0	817.6	1090.1	1362.6	1635.12
17	0.7	8.0	5.2	2.5	5.0	7.4	89.9	2.4	4.86
18	0.7	7.9	5.2	2.4	4.9	7.3	9.7	2.2	4.61
19	0.7	7.9	5.2	2.4	4.8	7.2	9.6	2.0	4.35
20	0.6	7.9	5.1	2.3	4.7	7.0	9.4	1.7	4.10
21	190.6	217.8	245.1	272.3	544.6	816.9	1089.2	1361.5	1633.84
22	0.6	7.8	5.0	2.3	4.5	6.8	9.1	1.3	3.59
23	0.6	7.8	5.0	2.2	4.4	6.7	8.9	1.1	3.33
24	0.5	7.7	5.0	2.2	4.4	6.6	8.7	0.9	3.08
25	0.5	7.7	4.9	2.1	4.3	6.4	8.6	0.7	2.82
26	190.5	217.7	244.9	272.1	544.2	816.3	1088.4	1360.5	1632.57
27	0.4	7.6	4.8	2.0	4.1	6.2	8.2	0.3	2.31
28	0.4	7.6	4.8	2.0	4.0	6.0	8.0	0.0	2.06
29	0.4	7.6	4.8	2.0	3.9	5.9	7.9	1359.8	1.80
30	0.3	7.5	4.7	1.9	3.8	5.8	7.7	9.6	1.54

Meridional arcs.	
1″	30.8
2	61.6
3	92.3
4	123.1
5	153.9
6	184.7
7	215.5
8	246.2
9	277.0
10	307.8
20	615.6
30	923.4
40	1231.2
50	1539.0
1′ 00	1846.8
2	3693.6
3	5540.4
4	7387.2
5	9234.0
6	11080.8
7	12927.6
8	14774.4
9	16621.2
10	18468.0
11	20314.8
12	22161.6

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.4
3	.0	1.0
4	.0	1.8
5	.0	2.8
6	.0	4.0
7	.0	5.5
8	.0	7.2
9	.0	9.1
10	.0	11.2
15	.0	25.2
20	.0	44.8
25	.1	70.0
30	.1	100.7
35	.2	137.1
40	.2	179.1
45	.3	226.6
50	.5	279.8
55	.6	338.6
1° 00	.8	402.9
1 10	1.3	548.4
1 20	2.0	716.3
1 30	2.8	906.6
1 40	3.8	1119.3
1 50	5.1	1354.3
2 00	6.6	1611.7

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 28° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	190. 3	217. 5	244. 7	271. 9	543. 8	815. 8	1087. 7	1359. 6	1631. 54
31	0. 3	7. 5	4. 7	1. 9	3. 8	5. 6	7. 5	9. 4	1. 29
32	0. 3	7. 5	4. 7	1. 8	3. 7	5. 5	7. 4	9. 2	1. 03
33	0. 3	7. 4	4. 6	1. 8	3. 6	5. 4	7. 2	9. 0	0. 77
34	0. 2	7. 4	4. 6	1. 7	3. 5	5. 3	7. 0	8. 8	0. 52
35	0. 2	7. 4	4. 5	1. 7	3. 4	5. 1	6. 8	8. 6	0. 26
36	190. 2	217. 3	244. 5	271. 7	543. 3	815. 0	1086. 7	1358. 3	1630. 00
37	0. 1	7. 3	4. 5	1. 6	3. 3	4. 9	6. 5	8. 1	29. 75
38	0. 1	7. 3	4. 4	1. 6	3. 2	4. 7	6. 3	7. 9	9. 49
39	0. 1	7. 2	4. 4	1. 5	3. 1	4. 6	6. 2	7. 7	9. 23
40	0. 0	7. 2	4. 4	1. 5	3. 0	4. 5	6. 0	7. 5	8. 97
41	190. 0	217. 2	244. 3	271. 5	542. 9	814. 4	1085. 8	1357. 3	1628. 71
42	0. 0	7. 1	4. 3	1. 4	2. 8	4. 2	5. 6	7. 0	8. 46
43	0. 0	7. 1	4. 2	1. 4	2. 7	4. 1	5. 5	6. 8	8. 20
44	189. 9	7. 1	4. 2	1. 3	2. 6	4. 0	5. 3	6. 6	7. 94
45	9. 9	7. 0	4. 2	1. 3	2. 6	3. 8	5. 1	6. 4	7. 68
46	189. 9	217. 0	244. 1	271. 2	542. 5	813. 7	1085. 0	1356. 2	1627. 42
47	9. 8	7. 0	4. 1	1. 2	2. 4	3. 6	4. 8	6. 0	7. 16
48	9. 8	6. 9	4. 0	1. 1	2. 3	3. 5	4. 6	5. 8	6. 91
49	9. 8	6. 9	4. 0	1. 1	2. 2	3. 3	4. 4	5. 5	6. 65
50	9. 7	6. 9	4. 0	1. 1	2. 1	3. 2	4. 3	5. 3	6. 39
51	189. 7	216. 8	243. 9	271. 0	542. 0	813. 1	1084. 1	1355. 1	1626. 13
52	9. 7	6. 8	3. 9	1. 0	2. 0	2. 9	3. 9	4. 9	5. 87
53	9. 7	6. 7	3. 8	0. 9	1. 9	2. 8	3. 8	4. 7	. 61
54	9. 6	6. 7	3. 8	0. 9	1. 8	2. 7	3. 6	4. 5	5. 35
55	9. 6	6. 7	3. 8	0. 8	1. 7	2. 5	3. 4	4. 2	5. 09
56	189. 6	216. 6	243. 7	270. 8	541. 6	812. 4	1083. 2	1354. 0	1624. 83
57	9. 5	6. 6	3. 7	0. 8	1. 5	2. 3	3. 0	3. 8	4. 57
58	9. 5	6. 6	3. 6	0. 7	1. 4	2. 2	2. 9	3. 6	4. 31
59	9. 5	6. 5	3. 6	0. 7	1. 4	2. 0	2. 7	3. 4	4. 05
69	9. 4	6. 5	3. 6	0. 6	1. 3	1. 9	2. 5	3. 1	3. 79

Meridional arcs.	
1″	30. 8
2	61. 6
3	92. 3
4	123. 1
5	153. 9
6	184. 7
7	215. 5
8	246. 3
9	277. 0
10	307. 8
20	615. 6
30	923. 5
40	1231. 3
50	1539. 1
1′ 00	1846. 9
2	3693. 9
3	5540. 8
4	7387. 7
5	9234. 7
6	11081. 6
7	12928. 6
8	14775. 5
9	16622. 4
10	18469. 4
11	20316. 3
12	22163. 2

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—. 0	. 1
2	. 0	. 5
3	. 0	1. 0
4	. 0	1. 8
5	. 0	2. 8
6	. 0	4. 1
7	. 0	5. 5
8	. 0	7. 2
9	. 0	9. 2
10	. 0	11. 3
15	. 0	25. 5
20	. 0	45. 3
25	. 1	70. 8
30	. 1	101. 9
35	. 2	138. 7
40	. 3	181. 2
45	. 4	229. 3
50	. 5	283. 1
55	. 7	342. 5
1° 00	. 8	407. 6
1 10	1. 3	554. 8
1 20	2. 0	724. 7
1 30	2. 9	917. 1
1 40	3. 9	1132. 3
1 50	5. 2	1370. 0
2 00	6. 8	1630. 5

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 29° 00″.

Min.	Length in metres of arcs of the parallel, (arc par.) 7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	189.4	216,5	243,6	270,6	541,3	811,9	1082,5	1353,1	1623,79
1	9.4	6.5	3.5	0,6	1.2	1,8	2.4	2,9	3.53
2	9.4	6.4	3.5	0,5	1.1	1,6	2.2	2.7	3.27
3	9.4	6.4	3.5	0.5	1.0	1,5	2.0	2,5	3.01
4	9.3	6.4	3.4	0.5	0.9	1.4	1.8	2.3	2,75
5	9.3	6.3	3.4	0.4	0.8	1,2	1,7	2.1	2.48
6	189.3	216.3	243.3	270.4	540.7	811,1	1081,5	1351,9	1622,22
7	9.2	6.3	3.3	0,3	0,7	1,0	1.3	1.6	1.96
8	9.2	6.2	3.3	0,3	0,6	0.8	1,1	1,4	1.70
9	9.2	6.2	3.2	0.2	0.5	0.7	1.0	1.2	1.44
10	9.1	6.2	3.2	0,2	0,4	0.6	0.8	1.0	1,18
11	189.1	216.1	243.1	270.2	540.3	810,5	1080,6	1350,8	1620,92
12	9.1	6.1	3.1	0.1	0.2	0,3	0.4	0,5	0.65
13	9.0	6.1	3.1	0.1	0.1	0,2	0,3	0,3	0.39
14	9.0	6.0	3.0	0.0	0.0	0.1	0.1	0.1	0.13
15	9.0	6.0	3.0	0.0	0 0	809.9	1079,9	49.9	1619.87
16	189.0	215.9	242.9	269.9	539.9	809,8	1079,7	1349,7	1619,60
17	8.9	5.9	2.9	9.9	9.8	9,7	9,6	9,4	9,34
18	8.9	5.9	2.9	9.8	9.7	9,5	9,4	9,2	9,08
19	8.9	5.8	2.8	9,8	9.6	9,4	9,2	9,0	8,82
20	8.8	5.8	2.8	9.8	9.5	9.3	9.1	8.8	8,55
21	188.8	215.8	242.7	269.7	539.4	809.1	1078.9	1348.6	1618,29
22	8.8	5.7	2.7	9.7	9.3	9.0	8.7	8.4	8.03
23	8.7	5.7	2.7	9.6	9,3	8,9	8,5	8.1	7,76
24	8.7	5,7	2.6	9.6	9.2	8,7	8,3	7.9	7.50
25	8.7	5.6	2.6	9.5	9.1	8.6	8,2	7.7	7.23
26	188.6	215,6	242,5	269,5	539,0	808.5	1078,0	1347.5	1616,97
27	8,6	5.6	2,5	9,5	8.9	8,4	7,8	7,3	6,71
28	8,6	5,5	2,5	9,4	8,8	8,2	7,6	7,0	6,44
29	8,6	5,5	2,4	9,4	8,7	8,1	7,5	6,8	6.18
30	8,5	5.5	2,4	9,3	8,6	8,0	7.3	6.6	5.91

Meridional arcs.	
1″	30.8
2	61.6
3	92,4
4	123,1
5	153,9
6	184,7
7	215.5
8	246,3
9	277,1
10	307,8
20	615,7
30	923.5
40	1231,4
50	1539,2
1′ 00	1847,1
2	3694,1
3	5541,2
4	7388,3
5	9235,3
6	11082,4
7	12929,5
8	14776,6
9	16623,7
10	18470,7
11	20317,8
12	22164,9

Co-ordinates of curvature. Minutes of longitude.	X. Arc par.	Y.
1′	—,0	.1
2	,0	.5
3	,0	1,0
4	.0	1.8
5	,0	2,9
6	,0	4,1
7	.0	5,6
8	,0	7,3
9	.0	9,3
10	,0	11,4
15	,0	25,8
20	,0	45,8
25	,1	71,6
30	,1	103,0
35	,2	140,3
40	,3	183,2
45	,4	231,9
50	,5	286,2
55	,7	346,4
1° 00	,9	412,2
1 10	1,4	561,0
1 20	2,1	732,8
1 30	2,9	927,4
1 40	4,0	1145,0
1 50	5,4	1385,4
2 00	7,0	1648,8

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 29° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)									Meridional arcs.		Co-ordinates of curvature.		
	7″	8″	9″	10″	20″	30″	40″	50″	60″			Minutes of longitude.	X. Arc par.	Y.
30′	188.5	215.5	242.4	269.3	538.6	808.0	1077.3	1346.6	1615.91	1″	30.8	1′	—.0	.1
31	8.5	5.4	2.3	9.3	8.6	7.8	7.1	6.4	5.65	2	61.6	2	.0	.5
32	8.5	5.4	2.3	9.2	8.5	7.7	6.9	6.1	5.38	3	92.4	3	.0	1.0
33	8.4	5.3	2.3	9.2	8.4	7.6	6.8	5.9	5.12	4	123.2	4	.0	1.9
34	8.4	5.3	2.2	9.1	8.3	7.4	6.6	5.7	4.85					
35	8.4	5.3	2.2	9.1	8.2	7.3	6.4	5.5	4.59	5	153.9	5	.0	2.9
										6	184.7	6	.0	4.2
36	188.3	215.2	242.1	269.1	538.1	807.2	1076.2	1345.3	1614.32	7	215.5	7	.0	5.7
37	8.3	5.2	2.1	9.0	8.0	7.0	6.0	5.0	4.06	8	246.3	8	.0	7.4
38	8.3	5.2	2.1	9.0	7.9	6.9	5.9	4.8	3.79	9	277.1	9	.0	9.4
39	8.2	5.1	2.0	8.9	7.8	6.8	5.7	4.6	3.53					
40	8.2	5.1	2.0	8.9	7.8	6.6	5.5	4.4	3.26	10	307.9	10	.0	11.6
										20	615.7	15	.0	26.0
41	188.2	215.1	241.9	268.8	537.7	806.5	1075.3	1344.2	1612.99	30	923.6	20	.0	46.3
42	8.2	5.0	1.9	8.8	7.6	6.4	5.2	3.9	2.72	40	1231.5	25	.1	72.3
43	8.1	5.0	1.9	8.7	7.5	6.2	5.0	3.7	2.46	50	1539.3	30	.1	104.1
44	8.1	5.0	1.8	8.7	7.4	6.1	4.8	3.5	2.19					
45	8.1	4.9	1.8	8.7	7.3	6.0	4.6	3.3	1.93	1′ 00	1847.2	35	.2	141.8
										2	3694.4	40	.3	185.2
46	188.0	214.9	241.7	268.6	537.2	805.8	1074.4	1343.1	1611.66	3	5541.6	45	.4	234.4
47	8.0	4.9	1.7	8.6	7.1	5.7	4.3	2.8	1.39	4	7388.8	50	.5	289.3
48	8.0	4.8	1.7	8.5	7.0	5.6	4.1	2.6	1.12	5	9236.0	55	.7	350.1
49	7.9	4.8	1.6	8.5	7.0	5.4	3.9	2.4	0.86	6	11083.3			
50	7.9	4.7	1.6	8.4	6.9	5.3	3.7	2.2	0.59			1° 00	.9	416.6
										7	12930.5	1 10	1.4	567.1
51	187.9	214.7	241.5	268.4	536.8	805.2	1073.5	1341.9	1610.32	8	14777.7	1 20	2.1	740.7
52	7.8	4.7	1.5	8.3	6.7	5.0	3.4	1.7	10.06	9	16624.9	1 30	3.0	937.4
53	7.8	4.6	1.5	8.3	6.6	4.9	3.2	1.5	09.79	10	18472.1	1 40	4.1	1157.3
54	7.8	4.6	1.4	8.3	6.5	4.8	3.0	1.3	09.52	11	20319.3	1 50	5.5	1400.3
55	7.7	4.6	1.4	8.2	6.4	4.6	2.8	1.1	09.26	12	22166.5	2 00	7.2	1666.4
56	187.7	214.5	241.3	268.2	536.3	804.5	1072.7	1340.8	1608.99					
57	7.7	4.5	1.3	8.1	6.2	4.4	2.5	0.6	8.72					
58	7.7	4.5	1.3	8.1	6.1	4.2	2.3	0.4	8.45					
59	7.6	4.4	1.2	8.0	6.1	4.1	2.1	0.1	8.18					
60	7.6	4.4	1.2	8.0	6.0	4.0	1.9	1339.9	1607.91					

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 30° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	187.6	214.4	241.2	268.0	536.0	804.0	1071.9	1339.9	1607.91
1	7.6	4.4	1.1	7.9	5.9	3.8	1.8	9.7	7.65
2	7.5	4.3	1.1	7.9	5.8	3.7	1.6	9.5	7.38
3	7.5	4.3	1.1	7.9	5.7	3.6	1.4	9.3	7.11
4	7.5	4.2	1.0	7.8	5.6	3.4	1.2	9.0	6.84
5	7.4	4.2	1.0	7.8	5.5	3.3	1.0	8.8	6.57
6	187.4	214.2	240.9	267.7	535.4	803.1	1070.9	1338.6	1606.30
7	7.4	4.1	0.9	7.7	5.3	3.0	0.7	8.4	6.03
8	7.3	4.1	0.9	7.6	5.3	2.9	0.5	8.1	5.76
9	7.3	4.1	0.8	7.6	5.2	2.7	0.3	7.9	5.49
10	7.3	4.0	0.8	7.5	5.1	2.6	0.1	7.7	5.22
11	187.2	214.0	240.7	267.5	535.0	802.5	1070.0	1337.5	1604.95
12	7.2	4.0	0.7	7.4	4.9	2.3	1069.8	7.2	4.68
13	7.2	3.9	0.7	7.4	4.8	2.2	9.6	7.0	4.41
14	7.1	3.9	0.6	7.4	4.7	2.1	9.4	6.8	4.14
15	7.1	3.8	0.6	7.3	4.6	1.9	9.2	6.6	3.87
16	187.1	213.8	240.5	267.3	534.5	801.8	1069.1	1336.3	1603.60
17	7.1	3.8	0.5	7.2	4.4	1.7	8.9	6.1	3.32
18	7.0	3.7	0.5	7.2	4.4	1.6	8.7	5.9	3.05
19	7.0	3.7	0.4	7.1	4.3	1.4	8.5	5.6	2.78
20	7.0	3.7	0.4	7.1	4.2	1.3	8.3	5.4	2.51
21	186.9	213.6	240.3	267.0	534.1	801.1	1068.2	1335.2	1602.24
22	6.9	3.6	0.3	7.0	4.0	1.0	8.0	5.0	1.97
23	6.9	3.6	0.3	7.0	3.9	0.8	7.8	4.7	1.70
24	6.8	3.5	0.2	6.9	3.8	0.7	7.6	4.5	1.43
25	6.8	3.5	0.2	6.9	3.7	0.6	7.4	4.3	1.15
26	186.8	213.5	240.1	266.8	533.6	800.4	1067.3	1334.1	1600.88
27	6.7	3.4	0.1	6.8	3.5	0.3	7.1	3.8	0.61
28	6.7	3.4	0.1	6.7	3.4	0.2	6.9	3.6	0.34
29	6.7	3.3	0.0	6.7	3.4	0.0	6.7	3.4	0.06
30	6.6	3.3	0.0	6.6	3.3	799.9	6.5	3.2	1599.79

Meridional arcs.	
1″	30.8
2	61.6
3	92.4
4	123.2
5	153.9
6	184.7
7	215.5
8	246.3
9	277.1
10	307.9
20	615.8
30	923.7
40	1231.5
50	1539.4
1′ 00	1847.3
2	3694.7
3	5542.0
4	7389.4
5	9236.7
6	11084.1
7	12931.5
8	14778.8
9	16626.2
10	18473.5
11	20320.8
12	22168.2

Co-ordinates of curvature..		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.1
4	.0	1.9
5	.0	2.9
6	.0	4.2
7	.0	5.7
8	.0	7.5
9	.0	9.5
10	.0	11.7
15	.0	26.3
20	.0	46.8
25	.1	73.1
30	.1	105.2
35	.2	143.2
40	.3	187.1
45	.4	236.8
50	.5	292.3
55	.7	353.7
1° 00	.9	421.0
1 10	1.5	573.0
1 20	2.2	748.4
1 30	3.1	947.1
1 40	4.2	1169.3
1 50	5.6	1414.8
2 00	7.3	1683.8

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 30° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)									Meridional arcs.		Co-ordinates of curvature.		
	7″	8″	9″	10″	20″	30″	40″	50″	60″			Minutes of longitude.	X. Arc par.	Y.
30′	186.6	213.3	240.0	266.6	533.3	799.9	1066.5	1333.2	1599.79	1″	30.8	1′	—.0	.1
31	6.6	3.3	239.9	6.6	3.2	9.8	6.3	2.9	9.52	2	61.6	2	.0	.5
32	6.6	3.2	9.9	6.5	3.1	9.6	6.2	2.7	9.25	3	92.4	3	.0	1.1
33	6.5	3.2	9.8	6.5	3.0	9.5	6.0	2.5	8.97	4	123.2	4	.0	1.9
34	6.5	3.2	9.8	6.5	2.9	9.4	5.8	2.3	8.70					
35	6.5	3.1	9.8	6.4	2.8	9.2	5.6	2.1	8.43	5	154.0	5	.0	3.0
										6	184.7	6	.0	4.3
36	186.4	213.1	239.7	266.4	532.7	799.1	1065.4	1331.8	1598.15	7	215.5	7	.0	5.8
37	6.4	3.1	9.7	6.3	2.6	8.9	5.3	1.6	7.88	8	246.3	8	.0	7.6
38	6.4	3.0	9.6	6.3	2.5	8.8	5.1	1.3	7.61	9	277.1	9	.0	9.6
39	6.4	3.0	9.6	6.2	2.4	8.7	4.9	1.1	7.33					
40	6.3	2.9	9.6	6.2	2.4	8.5	4.7	0.9	7.06	10	307.9	10	.0	11.8
										20	615.8	15	.0	26.6
41	186.3	212.9	239.5	266.1	532.3	798.4	1064.5	1330.6	1596.78	30	923.7	20	.0	47.2
42	6.3	2.9	9.5	6.1	2.2	8.3	4.3	0.4	6.51	40	1231.7	25	.1	73.8
43	6.2	2.8	9.4	6.0	2.1	8.1	4.1	0.2	6.24	50	1539.6	30	.1	106.3
44	6.2	2.8	9.4	6.0	2.0	8.0	4.0	0.0	5.96					
45	6.2	2.8	9.4	5.9	1.9	7.8	3.8	29.7	5.69	1′ 00	1847.5	35	.2	144.7
										2	3695.0	40	.3	189.0
46	186.1	212.7	239.3	265.9	531.8	797.7	1063.6	1329.5	1595.41	3	5542.5	45	.4	239.1
47	6.1	2.7	9.3	5.9	1.7	7.6	3.4	9.3	5.14	4	7390.0	50	.5	295.2
48	6.1	2.6	9.2	5.8	1.6	7.4	3.2	9.0	4.86	5	9237.4	55	.7	357.2
49	6.0	2.6	9.2	5.8	1.5	7.3	3.1	8.8	4.59	6	11084.9			
50	6.0	2.6	9.1	5.7	1.4	7.2	2.9	8.6	4.31			1° 00	.9	425.1
										7	12932.4	1 10	1.5	578.7
51	186.0	212.5	239.1	265.7	531.3	797.0	1062.7	1328.4	1594.04	8	14779.9	1 20	2.2	755.8
52	5.9	2.5	9.1	5.6	1.3	6.9	2.5	8.1	3.76	9	16627.4	1 30	3.2	956.5
53	5.9	2.5	9.0	5.6	1.2	6.7	2.3	7.9	3.48	10	18474.9	1 40	4.4	1180.9
54	5.9	2.4	9.0	5.5	1.1	6.6	2.1	7.7	3.21	11	20322.4	1 50	5.8	1428.9
55	5.8	2.4	8.9	5.5	1.0	6.5	2.0	7.4	2.93	12	22169.9	2 00	7.5	1700.6
56	185.8	212.4	238.9	265.4	530.9	796.3	1061.8	1327.2	1592.66					
57	5.8	2.3	8.8	5.4	0.8	6.2	1.6	7.0	2.38					
58	5.7	2.3	8.8	5.4	0.7	6.0	1.4	6.8	2.10					
59	5.7	2.3	8.8	5.3	0.6	5.9	1.2	6.5	1.83					
60	5.7	2.2	8.7	5.3	0.5	5.8	1.0	6.3	1.55					

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 31° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	185.7	212.2	238.7	265.3	530.5	795.8	1061.0	1326.3	1591.55
1	5.6	2.2	8.7	5.2	0.4	5.6	0.8	6.1	1.27
2	5.6	2.1	8.6	5.2	0.3	5.5	0.7	5.8	1.00
3	5.6	2.1	8.6	5.1	0.2	5.4	0.5	5.6	0.72
4	5.6	2.1	8.6	5.1	0.1	5.2	0.3	5.4	0.44
5	5.5	2.0	8.5	5.0	0.1	5.1	1060.1	5.1	1590.16
6	185.5	212.0	238.5	265.0	530.0	794.9	1059.9	1324.9	1589.89
7	5.5	1.9	8.4	4.9	529.9	4.8	9.7	4.7	9.61
8	5.4	1.9	8.4	4.9	9.8	4.7	9.6	4.4	9.33
9	5.4	1.9	8.4	4.8	9.7	4.5	9.4	4.2	9.05
10	5.4	1.8	8.3	4.8	9.6	4.4	9.2	4.0	8.78
11	185.3	211.8	238.3	264.7	529.5	794.2	1059.0	1323.7	1588.50
12	5.3	1.8	8.2	4.7	9.4	4.1	8.8	3.5	8.22
13	5.3	1.7	8.2	4.7	9.3	4.0	8.6	3.3	7.94
14	5.2	1.7	8.1	4.6	9.2	3.8	8.4	3.0	7.66
15	5.2	1.7	8.1	4.6	9.1	3.7	8.2	2.8	7.38
16	185.2	211.6	238.1	264.5	529.0	793.5	1058.1	1322.6	1587.10
17	5.1	1.6	8.0	4.5	8.9	3.4	7.9	2.4	6.82
18	5.1	1.5	8.0	4.4	8.8	3.3	7.7	2.1	6.54
19	5.1	1.5	7.9	4.4	8.8	3.1	7.5	1.9	6.27
20	5.0	1.5	7.9	4.3	8.7	3.0	7.3	1.7	5.99
21	185.0	211.4	237.9	264.3	528.6	792.9	1057.1	1321.4	1585.71
22	5.0	1.4	7.8	4.2	8.5	2.7	7.0	1.2	5.43
23	4.9	1.4	7.8	4.2	8.4	2.6	6.8	1.0	5.15
24	4.9	1.3	7.7	4.1	8.3	2.4	6.6	0.7	4.87
25	4.9	1.3	7.7	4.1	8.2	2.3	6.4	0.5	4.58
26	184.8	211.2	237.6	264.0	528.1	792.1	1056.2	1320.3	1584.30
27	4.8	1.2	7.6	4.0	8.0	2.0	6.0	0.0	4.02
28	4.8	1.2	7.6	4.0	7.9	1.9	5.8	1319.8	3.74
29	4.7	1.1	7.5	3.9	7.8	1.7	5.6	9.6	3.46
30	4.7	1.1	7.5	3.9	7.7	1.6	5.5	9.3	3.18

Meridional arcs.	
1″	30.8
2	61.6
3	92.4
4	123.2
5	154.0
6	184.8
7	215.5
8	246.3
9	277.1
10	307.9
20	615.9
30	923.8
40	1231.7
50	1539.7
1′ 00	1847.6
2	3695.3
3	5542.9
4	7390.5
5	9238.1
6	11085.8
7	12933.4
8	14781.1
9	16628.7
10	18476.3
11	20324.0
12	22171.6

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.1
4	.0	1.9
5	.0	3.0
6	.0	4.3
7	.0	5.8
8	.0	7.6
9	.0	9.7
10	.0	11.9
15	.0	26.8
20	.0	47.7
25	.1	74.5
30	.1	107.3
35	.2	146.0
40	.3	190.8
45	.4	241.4
50	.6	298.0
55	.7	360.6
1° 00	1.0	429.2
1 10	1.5	584.2
1 20	2.3	763.0
1 30	3.3	965.7
1 40	4.5	1192.2
1 50	5.9	1442.5
2 00	7.7	1716.7

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 31° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.) 7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	184.7	211.1	237.5	263.9	527.7	791.6	1055.5	1319.3	1583.18
31	4.7	1.1	7.4	3.8	7.6	1.5	5.3	9.1	2.90
32	4.6	1.0	7.4	3.8	7.5	1.3	5.1	8.9	2.62
33	4.6	1.0	7.4	3.7	7.4	1.2	4.9	8.6	2.34
34	4.6	0.9	7.3	3.7	7.4	1.0	4.7	8.4	2.06
35	4.5	0.9	7.3	3.6	7.3	0.9	4.5	8.1	1.78
36	184.5	210.9	237.2	263.6	527.2	790.7	1054.3	1317.9	1581.50
37	4.5	0.8	7.2	3.5	7.1	0.6	4.1	7.7	1.21
38	4.4	0.8	7.1	3.5	7.0	0.5	4.0	7.4	0.93
39	4.4	0.8	7.1	3.4	6.9	0.3	3.8	7.2	0.65
40	4.4	0.7	7.1	3.4	6.8	0.2	3.6	7.0	0.37
41	184.3	210.7	237.0	263.3	526.7	790.0	1053.4	1316.7	1580.09
42	4.3	0.6	7.0	3.3	6.6	789.9	3.2	6.5	79.80
43	4.3	0.6	6.9	3.2	6.5	9.8	3.0	6.3	9.52
44	4.2	0.6	6.9	3.2	6.4	9.6	2.8	6.0	9.24
45	4.2	0.5	6.8	3.2	6.3	9.5	2.6	5.8	8.96
46	184.2	210.5	236.8	263.1	526.2	789.3	1052.5	1315.6	1578.67
47	4.1	0.5	6.8	3.1	6.1	9.2	2.3	5.3	8.39
48	4.1	0.4	6.7	3.0	6.0	9.1	2.1	5.1	8.11
49	4.1	0.4	6.7	3.0	5.9	8.9	1.9	4.9	7.82
50	4.0	0.3	6.6	2.9	5.8	8.8	1.7	4.6	7.54
51	184.0	210.3	236.6	262.9	525.8	788.6	1051.5	1314.4	1577.26
52	4.0	0.3	6.5	2.8	5.7	8.5	1.3	4.1	6.97
53	3.9	0.2	6.5	2.8	5.6	8.3	1.1	3.9	6.69
54	3.9	0.2	6.5	2.7	5.5	8.2	0.9	3.7	6.41
55	3.9	0.1	6.4	2.7	5.4	8.1	0.8	3.4	6.12
56	183.8	210.1	236.4	262.6	525.3	787.9	1050.6	1313.2	1575.84
57	3.8	0.1	6.3	2.6	5.2	7.8	0.4	3.0	5.55
58	3.8	0.0	6.3	2.5	5.1	7.6	0.2	2.7	5.27
59	3.7	0.0	6.2	2.5	5.0	7.5	0.0	2.5	4.98
60	3.7	0.0	6.2	2.4	4.9	7.3	1049.8	2.2	4.70

Meridional arcs.	
1″	30.8
2	61.6
3	92.4
4	123.2
5	154.0
6	184.8
7	215.6
8	246.4
9	277.2
10	308.0
20	615.9
30	923.9
40	1231.8
50	1539.8
1′ 00	1847.8
2	3695.5
3	5543.3
4	7391.1
5	9238.9
6	11086.7
7	12934.4
8	14782.2
9	16630.0
10	18477.8
11	20325.5
12	22173.3

Co-ordinates of curvature. Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.1
4	.0	1.9
5	.0	3.0
6	.0	4.3
7	.0	5.9
8	.0	7.7
9	.0	9.7
10	.0	12.0
15	.0	27.1
20	.0	48.1
25	.1	75.2
30	.1	108.4
35	.2	147.4
40	.3	192.5
45	.4	243.6
50	.6	300.8
55	.8	364.0
1° 00	1.0	433.1
1 10	1.6	589.5
1 20	2.3	770.0
1 30	3.3	974.5
1 40	4.6	1203.1
1 50	6.1	1455.8
2 00	7.9	1732.5

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 32° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)									Meridional arc.		Co-ordinates of curvature.		
	7″	8″	9″	10″	20″	30″	40″	50″	60″			Minutes of longitude.	X. Arc par.	Y.
0′	183.7	210.0	236.2	262.4	524.9	787.3	1049.8	1312.2	1574.70	1″	30.8	1′	—.0	.1
1	3.7	209.9	6.2	2.4	4.8	7.2	9.6	2.0	4.41	2	61.6	2	.0	.5
2	3.6	9.9	6.1	2.3	4.7	7.1	9.4	1.8	4.13	3	92.4	3	.0	1.1
3	3.6	9.8	6.1	2.3	4.6	6.9	9.2	1.5	3.84	4	123.2	4	.0	1.9
4	3.6	9.8	6.0	2.3	4.5	6.8	9.0	1.3	3.56					
5	3.5	9.8	6.0	2.2	4.4	6.6	8.9	1.1	3.27	5	154.0	5	.0	3.0
										6	184.8	6	.0	4.3
6	183.5	209.7	235.9	262.2	524.3	786.5	1048.7	1310.8	1572.98	7	215.6	7	.0	5.9
7	3.5	9.7	5.9	2.1	4.2	6.3	8.5	0.6	2.70	8	246.4	8	.0	7.8
8	3.4	9.7	5.9	2.1	4.1	6.2	8.3	0.3	2.41	9	277.2	9	.0	9.8
9	3.4	9.6	5.8	2.0	4.0	6.1	8.1	0.1	2.13					
10	3.4	9.6	5.8	2.0	3.9	5.9	7.9	1309.9	1.84	10	308.0	10	.0	12.1
										20	616.0	15	.0	27.3
11	183.3	209.5	235.7	261.9	523.9	785.8	1047.7	1309.6	1571.55	30	924.0	20	.0	48.5
12	3.3	9.5	5.7	1.9	3.8	5.6	7.5	9.4	1.27	40	1231.9	25	.1	75.9
13	3.3	9.5	5.6	1.8	3.7	5.5	7.3	9.1	0.98	50	1539.9	30	.1	109.2
14	3.2	9.4	5.6	1.8	3.6	5.3	7.1	8.9	0.70					
15	3.2	9.4	5.6	1.7	3.5	5.2	6.9	8.7	0.41	1′ 00	1847.9	35	.2	148.7
										2	3695.8	40	.3	194.2
16	183.2	209.3	235.5	261.7	523.4	785.1	1046.7	1308.4	1570.12	3	5543.8	45	.4	245.8
17	3.1	9.3	5.5	1.6	3.3	4.9	6.5	8.2	69.83	4	7391.7	50	.6	303.4
18	3.1	9.3	5.4	1.6	3.2	4.8	6.4	8.0	9.55	5	9239.6	55	.8	367.1
19	3.1	9.2	5.4	1.5	3.1	4.6	6.2	7.7	9.26	6	11087.5			
20	3.0	9.2	5.4	1.5	3.0	4.5	6.0	7.5	8.97			1° 00	1.0	436.9
										7	12935.4	1 10	1.6	594.7
21	183.0	209.2	235.3	261.4	522.9	784.3	1045.8	1307.2	1568.68	8	14783.4	1 20	2.4	776.7
22	3.0	9.1	5.3	1.4	2.8	4.2	5.6	7.0	8.40	9	16631.3	1 30	3.4	983.0
23	2.9	9.1	5.2	1.4	2.7	4.1	5.4	6.8	8.11	10	18479.2	1 40	4.7	1213.7
24	2.9	9.0	5.2	1.3	2.6	3.9	5.2	6.5	7.83	11	20327.1	1 50	6.2	1468.5
25	2.9	9.0	5.1	1.3	2.5	3.8	5.0	6.3	7.54	12	22175.0	2 00	8.1	1747.6
26	182.8	209.0	235.1	261.2	522.4	783.6	1044.8	1306.0	1567.25					
27	2.8	8.9	5.0	1.2	2.3	3.5	4.6	5.8	6.96					
28	2.8	8.9	5.0	1.1	2.2	3.3	4.4	5.6	6.67					
29	2.7	8.8	5.0	1 1	2.1	3.2	4.3	5.3	6.38					
30	2.7	8.8	4.9	1.0	2.0	3.0	4.1	5.1	6.09					

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 32° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	182.7	208.8	234.9	261.0	522.0	783.0	1044.1	1305.1	1566.09
31	2.7	8.8	4.9	1.0	1.9	2.9	3.9	4.8	5.80
32	2.6	8.7	4.8	0.9	1.8	2.8	3.7	4.6	5.51
33	2.6	8.7	4.8	0.9	1.7	2.6	3.5	4.4	5.23
34	2.6	8.7	4.7	0.8	1.6	2.5	3.3	4.1	4.94
35	2.5	8.6	4.7	0.8	1.5	2.3	3.1	3.9	4.65
36	182.5	208.6	234.6	260.7	521.5	782.2	1042.9	1303.6	1564.36
37	2.5	8.5	4.6	0.7	1.4	2.0	2.7	3.4	4.07
38	2.4	8.5	4.6	0.6	1.3	1.9	2.5	3.1	3.78
39	2.4	8.5	4.5	0.6	1.2	1.7	2.3	2.9	3.49
40	2.4	8.4	4.5	0.5	1.1	1.6	2.1	2.7	3.20
41	182.3	208.4	234.4	260.5	521.0	781.5	1041.9	1302.4	1562.91
42	2.3	8.4	4.4	0.4	0.9	1.3	1.8	2.2	2.62
43	2.3	8.3	4.3	0.4	0.8	1.2	1.6	1.9	2.33
44	2.2	8.3	4.3	0.3	0.7	1.0	1.4	1.7	2.04
45	2.2	8.2	4.3	0.3	0.6	0.9	1.2	1.5	1.75
46	182.2	208.2	234.2	260.2	520.5	780.7	1041.0	1301.2	1561.46
47	2.1	8.2	4.2	0.2	0.4	0.6	0.8	1.0	1.17
48	2.1	8.1	4.1	0.1	0.3	0.4	0.6	0.7	0.87
49	2.1	8.1	4.1	0.1	0.2	0.3	0.4	0.5	0.58
50	2.0	8.0	4.0	0.0	0.1	0.2	0.2	0.3	0.29
51	182.0	208.0	234.0	260.0	520.0	780.0	1040.0	1300.0	1560.00
52	2.0	8.0	4.0	0.0	519.9	779.9	39.8	1299.8	59.71
53	1.9	7.9	3.9	259.9	9.8	9.7	9.6	9.5	9.41
54	1.9	7.9	3.9	9.9	9.7	9.6	9.4	9.3	9.12
55	1.9	7.8	3.8	9.8	9.6	9.4	9.2	9.0	8.83
56	181.8	207.8	233.8	259.8	519.5	779.3	1039.0	1298.8	1558.54
57	1.8	7.8	3.7	9.7	9.4	9.1	8.8	8.5	8.25
58	1.8	7.7	3.7	9.7	9.3	9.0	8.6	8.3	7.95
59	1.7	7.7	3.6	9.6	9.2	8.8	8.4	8.0	7.66
60	1.7	7.6	3.6	9.6	9.1	8.7	8.3	7.8	7.37

Meridional arcs.	
1″	30.8
2	61.6
3	92.4
4	123.2
5	154.0
6	184.8
7	215.6
8	246.4
9	277.2
10	308.0
20	616.0
30	924.0
40	1232.1
50	1540.1
1′ 00	1848.1
2	3696.1
3	5544.2
4	7392.3
5	9240.3
6	11088.4
7	12936.5
8	14784.5
9	16632.6
10	18480.7
11	20328.7
12	22176.8

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.1
4	.0	2.0
5	.0	3.1
6	.0	4.4
7	.0	6.0
8	.0	7.8
9	.0	9.9
10	.0	12.2
15	.0	27.5
20	.0	49.0
25	.1	76.5
30	.1	110.1
35	.2	149.9
40	.3	195.8
45	.4	247.8
50	.6	306.0
55	.8	370.2
1° 00	1.0	440.6
1 10	1.6	599.7
1 20	2.4	783.3
1 30	3.5	991.3
1 40	4.8	1223.9
1 50	6.4	1480.9
2 00	8.3	1762.4

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 33° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	181.7	207.6	233.6	259.6	519.1	778.7	1038.3	1297.8	1557.37
1	1.7	7.6	3.6	9.5	9.0	8.5	8.1	7.6	7.08
2	1.6	7.6	3.5	9.5	8.9	8.4	7.9	7.3	6.78
3	1.6	7.5	3.5	9.4	8.8	8.2	7.7	7.1	6.49
4	1.6	7.5	3.4	9.4	8.7	8.1	7.5	6.8	6.19
5	1.5	7.5	3.4	9.3	8.6	8.0	7.3	6.6	5.90
6	181.5	207.4	233.3	259.3	518.5	777.8	1037.1	1296.3	1555.61
7	1.5	7.4	3.3	9.2	8.4	7.7	6.9	6.1	5.31
8	1.4	7.3	3.3	9.2	8.3	7.5	6.7	5.8	5.02
9	1.4	7.3	3.2	9.1	8.2	7.4	6.5	5.6	4.72
10	1.3	7.3	3.2	9.1	8.1	7.2	6.3	5.4	4.43
11	181.3	207.2	233.1	259.0	518.0	777.1	1036.1	1295.1	1554.14
12	1.3	7.2	3.1	9.0	7.9	6.9	5.9	4.9	3.84
13	1.2	7.1	3.0	8.9	7.8	6.8	5.7	4.6	3.55
14	1.2	7.1	3.0	8.9	7.7	6.6	5.5	4.4	3.25
15	1.2	7.1	2.9	8.8	7.7	6.5	5.3	4.1	2.96
16	181.1	207.0	232.9	258.8	517.6	776.3	1035.1	1293.9	1552.66
17	1.1	7.0	2.8	8.7	7.5	6.2	4.9	3.6	2.37
18	1.1	6.9	2.8	8.7	7.4	6.0	4.7	3.4	2.07
19	1.0	6.9	2.8	8.6	7.3	5.9	4.5	3.1	1.78
20	1.0	6.9	2.7	8.6	7.2	5.7	4.3	2.9	1.48
21	181.0	206.8	232.7	258.5	517.1	775.6	1034.1	1292.7	1551.19
22	0.9	6.8	2.6	8.5	7.0	5.4	3.9	2.4	0.89
23	0.9	6.7	2.6	8.4	6.9	5.3	3.7	2.2	0.60
24	0.9	6.7	2.5	8.4	6.8	5.1	3.5	1.9	0.30
25	0.8	6.7	2.5	8.3	6.7	5.0	3.3	1.7	0.01
26	0.8	206.6	232.5	258.3	516.6	774.9	1033.1	1291.4	1549.71
27	0.8	6.6	2.4	8.2	6.5	4.7	2.9	1.2	9.41
28	0.7	6.5	2.4	8.2	6.4	4.6	2.7	0.9	9.12
29	0.7	6.5	2.3	8.1	6.3	4.4	2.5	0.7	8.82
30	0.7	6.5	2.3	8.1	6.2	4.3	2.3	0.4	8.52

Meridional arcs.	
1″	30.8
2	61.6
3	92.4
4	123.2
5	154.0
6	184.8
7	215.6
8	246.4
9	277.2
10	308.0
20	616.1
30	924.1
40	1232.1
50	1540.2
1′ 00	1848.2
2	3696.4
3	5544.6
4	7392.8
5	9241.0
6	11089.3
7	12937.5
8	14785.7
9	16633.9
10	18482.1
11	20330.3
12	22178.6

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.1
4	.0	2.0
5	.0	3.1
6	.0	4.4
7	.0	6.0
8	.0	7.9
9	.0	10.0
10	.0	12.3
15	.0	27.8
20	.0	49.3
25	.1	77.1
30	.1	111.0
35	.2	151.1
40	.3	197.4
45	.4	249.8
50	.6	308.4
55	.8	373.2
1° 00	1.1	444.1
1 10	1.7	604.5
1 20	2.5	789.5
1 30	3.6	999.3
1 40	4.9	1233.7
1 50	6.5	1492.8
2 00	8.5	1776.4

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 33° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)									Meridional arcs.		Co-ordinates of curvature.		
	7″	8″	9″	10″	20″	30″	40″	50″	60″			Minutes of longitude.	X. Arc par.	Y.
30′	180.7	206.5	232.3	258.1	516.2	774.3	1032.3	1290.4	1548.52	1″	30.8	1′	—.0	.1
31	0.6	6.4	2.2	8.0	6.1	4.1	2.1	0.2	8.22	2	61.6	2	.0	.5
32	0.6	6.4	2.2	8.0	6.0	4.0	2.0	89.9	7.93	3	92.4	3	.0	1.1
33	0.6	6.4	2.1	7.9	5.9	3.8	1.8	9.7	7.63	4	123.2	4	.0	2.0
34	0.5	6.3	2.1	7.9	5.8	3.7	1.6	9.5	7.34					
35	0.5	6.3	2.1	7.8	5.7	3.5	1.4	9.2	7.04	5	154.0	5	.0	3.1
										6	184.8	6	.0	4.5
36	180.5	206.2	232.0	257.8	515.6	773.4	1031.2	1289.0	1546.74	7	215.6	7	.0	6.1
37	0.4	6.2	2.0	7.7	5.5	3.2	1.0	8.7	6.44	8	246.4	8	.0	8.0
38	0.4	6.2	1.9	7.7	5.4	3.1	0.8	8.5	6.15	9	277.3	9	.0	10.1
39	0.3	6.1	1.9	7.6	5.3	2.9	0.6	8.2	5.85					
40	0.3	6.1	1.8	7.6	5.3	2.8	0.4	8.0	5.55	10	308.1	10	.0	12.4
										20	616.1	15	.0	28.0
41	180.3	206.0	231.8	257.5	515.1	772.6	1030.2	1287.7	1545.25	30	924.2	20	.0	49.7
42	0.2	6.0	1.7	7.5	5.0	2.5	30.0	7.5	4.95	40	1232.2	25	.1	77.7
43	0.2	6.0	1.7	7.4	4.9	2.3	29.8	7.2	4.66	50	1540.3	30	.1	111.9
44	0.2	5.9	1.7	7.4	4.8	2.2	9.6	7.0	4.36					
45	0.1	5.9	1.6	7.3	4.7	2.0	9.4	6.7	4.06	1′ 00	1848.4	35	.2	152.3
										2	3696.7	40	.3	198.9
46	180.1	205.8	231.6	257.3	514.6	771.9	1029.2	1286.5	1543.76	3	5545.1	45	.5	251.5
47	0.1	5.8	1.5	7.2	4.5	1.7	9.0	6.2	3.46	4	7393.5	50	.6	310.7
48	0.0	5.8	1.5	7.2	4.4	1.6	8.8	6.0	3.16	5	9241.8	55	.8	376.0
49	0.0	5.7	1.4	7.1	4.3	1.4	8.6	5.7	2.86	6	11090.2			
50	0.0	5.7	1.4	7.1	4.2	1.3	8.4	5.5	2.56			1° 00	1.1	447.5
										7	12938.5	1 10	1.7	609.1
51	179.9	205.6	231.3	257.0	514.1	771.1	1028.2	1285.2	1542.26	8	14786.9	1 20	2.6	795.6
52	9.9	5.6	1.3	7.0	4.0	1.0	8.0	5.0	1.96	9	16635.3	1 30	3.6	1006.9
53	9.9	5.6	1.3	6.9	3.9	0.8	7.8	4.7	1.66	10	18483.6	1 40	5.0	1243.1
54	9.8	5.5	1.2	6.9	3.8	0.7	7.6	4.5	1.36	11	20332.0	1 50	6.6	1504.1
55	9.8	5.5	1.2	6.8	3.7	0.5	7.4	4.2	1.06	12	22180.4	2 00	8.6	1790.0
56	179.8	205.4	231.1	256.8	513.6	770.4	1027.2	1284.0	1540.76					
57	9.7	5.4	1.1	6.7	3.5	0.2	7.0	3.7	0.46					
58	9.7	5.4	1.0	6.7	3.4	0.1	6.8	3.5	0.16					
59	9.6	5.3	1.0	6.6	3.3	769.9	6.6	3.2	39.86					
60	9.6	5.3	0.9	6.6	3.2	9.8	6.4	3.0	1539.56					

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 34° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	179.6	205.3	230.9	256.6	513.2	769.8	1026.4	1283.0	1539.56
1	9.6	5.2	0.9	6.5	3.1	9.6	6.2	2.7	9.26
2	9.5	5.2	0.8	6.5	3.0	9.5	6.0	2.5	8.96
3	9.5	5.2	0.8	6.4	2.9	9.3	5.8	2.2	8.66
4	9.5	5.1	0.8	6.4	2.8	9.2	5.6	2.0	8.36
5	9.4	5.1	0.7	6.3	2.7	9.0	5.4	1.7	8.06
6	179.4	205.0	230.7	256.3	512.6	768.9	1025.2	1281.5	1537.76
7	9.4	5.0	0.6	6.2	2.5	8.7	5.0	1.2	7.45
8	9.3	5.0	0.6	6.2	2.4	8.6	4.8	1.0	7.15
9	9.3	4.9	0.5	6.1	2.3	8.4	4.6	0.7	6.85
10	9.3	4.9	0.5	6.1	2.2	8.3	4.4	0.5	6.55
11	179.2	204.8	230.4	256.0	512.1	768.1	1024.2	1280.2	1536.25
12	9.2	4.8	0.4	6.0	2.0	8.0	4.0	0.0	5.95
13	9.2	4.8	0.4	5.9	1.9	7.8	3.8	79.7	5.64
14	9.1	4.7	0.3	5.9	1.8	7.7	3.6	9.5	5.34
15	9.1	4.7	0.3	5.8	1.7	7.5	3.4	9.2	5.04
16	179.1	204.6	230.2	255.8	511.6	767.4	1023.2	1279.0	1534.74
17	9.0	4.6	0.2	5.7	1.5	7.2	3.0	8.7	4.43
18	9.0	4.6	0.1	5.7	1.4	7.1	2.8	8.4	4.13
19	8.9	4.5	0.1	5.6	1.3	6.9	2.6	8.2	3.83
20	8.9	4.5	0.0	5.6	1.2	6.8	2.3	7.9	3.53
21	178.9	204.4	230.0	255.5	511.1	766.6	1022.1	1277.7	1533.22
22	8.8	4.4	29.9	5.5	1.0	6.5	1.9	7.4	2.92
23	8.8	4.3	9.9	5.4	0.9	6.3	1.7	7.2	2.61
24	8.8	4.3	9.8	5.4	0.8	6.2	1.5	6.9	2.31
25	8.7	4.3	9.8	5.3	0.7	6.0	1.3	6.7	2.00
26	178.7	204.2	229.8	255.3	510.6	765.8	1021.1	1266.4	1531.70
27	8.7	4.2	9.7	5.2	0.5	5.7	0.9	6.2	1.40
28	8.6	4.1	9.7	5.2	0.4	5.5	0.7	5.9	1.09
29	8.6	4.1	9.6	5.1	0.3	5.4	0.5	5.6	0.79
30	8.6	4.1	9.6	5.1	0.2	5.2	0.3	5.4	0.48

Meridional arcs.	
1″	30.8
2	61.6
3	92.4
4	123.2
5	154.0
6	184.9
7	215.7
8	246.5
9	277.3
10	308.1
20	616.2
30	924.3
40	1232.3
50	1540.4
1′ 00	1848.5
2	3697.0
3	5545.5
4	7394.0
5	9242.6
6	11091.1
7	12939.6
8	14788.1
9	16636.6
10	18485.1
11	20333.6
12	22182.1

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.1
4	.0	2.0
5	.0	3.1
6	.0	4.5
7	.0	6.1
8	.0	8.0
9	.0	10.1
10	.0	12.5
15	.0	28.2
20	.0	50.1
25	.1	78.3
30	.1	112.7
35	.2	153.4
40	.3	200.4
45	.5	253.5
50	.6	313.0
55	.8	378.8
1° 00	1.1	450.8
1 10	1.7	613.6
1 20	2.6	801.4
1 30	3.7	1014.2
1 40	5.1	1252.2
1 50	6.8	1515.1
2 00	8.8	1803.1

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 34° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	178.6	204.1	229.6	255.1	510.2	765.2	1020.3	1275.4	1530.48
31	8.5	4.0	9.5	5.0	0.1	5.1	0.1	5.1	0.18
32	8.5	4.0	9.5	5.0	0.0	4.9	19.9	4.9	29.87
33	8.4	3.9	9.4	4.9	509.9	4.8	9.7	4.6	9.57
34	8.4	3.9	9.4	4.9	9.8	4.6	9.5	4.4	9.26
35	8.4	3.9	9.3	4.8	9.7	4.5	9.3	4.1	8.96
36	178.3	203.8	229.3	254.8	509.5	764.3	1019.1	1273.9	1528.65
37	8.3	3.8	9.3	4.7	9.4	4.2	8.9	3.6	8.35
38	8.3	3.7	9.2	4.7	9.3	4.0	8.7	3.4	8.04
39	8.2	3.7	9.2	4.6	9.2	3.9	8.5	3.1	7.74
40	8.2	3.7	9.1	4.6	9.1	3.7	8.3	2.9	7.43
41	178.2	203.6	229.1	254.5	509.0	763.6	1018.1	1272.6	1527.13
42	8.1	3.6	9.0	4.5	8.9	3.4	7.9	2.4	6.82
43	8.1	3.5	9.0	4.4	8.8	3.3	7.7	2.1	6.51
44	8.1	3.5	8.9	4.4	8.7	3.1	7.5	1.8	6.21
45	8.0	3.5	8.9	4.3	8.6	2.9	7.3	1.6	5.90
46	178.0	203.4	228.8	254.3	508.5	762.8	1017.1	1271.3	1525.59
47	8.0	3.4	8.8	4.2	8.4	2.6	6.9	1.1	5.29
48	7.9	3.3	8.7	4.2	8.3	2.5	6.7	0.8	4.98
49	7.9	3.3	8.7	4.1	8.2	2.3	6.5	0.6	4.67
50	7.8	3.3	8.7	4.1	8.1	2.2	6.3	0.3	4.37
51	177.8	203.2	228.6	254.0	508.0	762.0	1016.0	1270.0	1524.06
52	7.8	3.2	8.6	4.0	7.9	1.9	5.8	69.8	3.75
53	7.7	3.1	8.5	3.9	7.8	1.7	5.6	9.5	3.44
54	7.7	3.1	8.5	3.9	7.7	1.6	5.4	9.3	3.14
55	7.7	3.0	8.4	3.8	7.6	1.4	5.2	9.0	2.83
56	177.6	203.0	228.4	253.8	507.5	761.3	1015.0	1268.8	1522.52
57	7.6	3.0	8.3	3.7	7.4	1.1	4.8	8.5	2.21
58	7.6	2.9	8.3	3.6	7.3	0.9	4.6	8.3	1.90
59	7.5	2.9	8.2	3.6	7.2	0.8	4.4	8.0	1.60
60	7.5	2.8	8.2	3.5	7.1	0.6	4.2	7.7	1.29

Meridional arcs.	
1″	30.8
2	61.6
3	92.4
4	123.2
5	154.1
6	184.9
7	215.7
8	246.5
9	277.3
10	308.1
20	616.2
30	924.3
40	1232.4
50	1540.6
1′ 00	1848.7
2	3697.3
3	5546.0
4	7394.6
5	9243.3
6	11092.0
7	12940.6
8	14789.3
9	16638.0
10	18486.6
11	20335.3
12	22183.9

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.1
4	.0	2.0
5	.0	3.1
6	.0	4.5
7	.0	6.2
8	.0	8.1
9	.0	10.2
10	.0	12.6
15	.0	28.4
20	.0	50.4
25	.1	78.8
30	.1	113.5
35	.2	154.5
40	.3	201.7
45	.5	255.3
50	.7	315.2
55	.9	381.4
1° 00	1.1	453.9
1 10	1.8	617.8
1 20	2.7	806.9
1 30	3.8	1021.2
1 40	5.2	1260.8
1 50	6.9	1525.6
2 00	9.0	1815.5

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 35° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	177.5	202.8	228.2	253.5	507.1	760.6	1014.2	1267.7	1521.29
1	7.4	2.8	8.1	3.5	7.0	0.5	4.0	7.5	0.98
2	7.4	2.8	8.1	3.4	6.9	0.3	3.8	7.2	0.67
3	7.4	2.7	8.1	3.4	6.8	0.2	3.6	7.0	0.36
4	7.3	2.7	8.0	3.3	6.7	0.0	3.4	6.7	0.05
5	7.3	2.6	8.0	3.3	6.6	59.9	3.2	6.4	19.74
6	177.3	202.6	227.9	253.2	506.5	759.7	1013.0	1266.2	1519.43
7	7.2	2.5	7.9	3.2	6.4	9.6	2.8	5.9	9.13
8	7.2	2.5	7.8	3.1	6.3	9.4	2.5	5.7	8.82
9	7.2	2.5	7.8	3.1	6.2	9.3	2.3	5.4	8.51
10	7.1	2.4	7.7	3.0	6.1	9.1	2.1	5.2	8.20
11	177.1	202.4	227.7	253.0	506.0	758.9	1011.9	1264.9	1517.89
12	7.1	2.3	7.6	2.9	5.9	8.8	1.7	4.6	7.58
13	7.0	2.3	7.6	2.9	5.8	8.6	1.5	4.4	7.27
14	7.0	2.3	7.5	2.8	5.6	8.5	1.3	4.1	6.96
15	6.9	2.2	7.5	2.8	5.5	8.3	1.1	3.9	6.65
16	176.9	202.2	227.5	252.7	505.4	758.2	1010.9	1263.6	1516.34
17	6.9	2.1	7.4	2.7	5.3	8.0	0.7	3.4	6.03
18	6.8	2.1	7.4	2.6	5.2	7.9	0.5	3.1	5.71
19	6.8	2.1	7.3	2.6	5.1	7.7	0.3	2.8	5.40
20	6.8	2.0	7.3	2.5	5.0	7.5	0.1	2.6	5.09
21	176.7	202.0	227.2	252.5	504.9	757.4	1009.9	1262.3	1514.78
22	6.7	1.9	7.2	2.4	4.8	7.2	9.6	2.1	4.47
23	6.7	1.9	7.1	2.4	4.7	7.1	9.4	1.8	4.16
24	6.6	1.8	7.1	2.3	4.6	6.9	9.2	1.5	3.85
25	6.6	1.8	7.0	2.3	4.5	6.8	9.0	1.3	3.54
26	176.5	201.8	227.0	252.2	504.4	756.6	1008.8	1261.0	1513.22
27	6.5	1.7	6.9	2.2	4.3	6.5	8.6	0.8	2.91
28	6.5	1.7	6.9	2.1	4.2	6.3	8.4	0.5	2.60
29	6.4	1.6	6.8	2.0	4.1	6.1	8.2	0.2	2.29
30	6.4	1.6	6.8	2.0	4.0	6.0	8.0	0.0	1.98

Meridional arcs.	
1″	30.8
2	61.6
3	92.4
4	123.2
5	154.1
6	184.9
7	215.7
8	246.5
9	277.3
10	308.1
20	616.2
30	924.4
40	1232.5
50	1540.6
1′ 00	1848.8
2	3697.6
3	5546.4
4	7395.2
5	9244.0
6	11092.9
7	12941.7
8	14790.5
9	16639.3
10	18488.2
11	20337.0
12	22185.8

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.1
4	.0	2.0
5	.0	3.2
6	.0	4.6
7	.0	6.2
8	.0	8.1
9	.0	10.3
10	.0	12.7
15	.0	28.6
20	.0	50.8
25	.1	79.3
30	.1	114.2
35	.2	155.5
40	.3	203.0
45	.5	257.0
50	.7	317.3
55	.9	383.9
1° 00	1.1	456.9
1 10	1.8	621.9
1 20	2.7	812.2
1 30	3.9	1028.0
1 40	5.3	1269.1
1 50	7.0	1535.6
2 00	9.1	1827.5

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 35° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7′′	8′′	9′′	10′′	20′′	30′′	40′′	50′′	60′′
30′	176.4	201.6	226.8	252.0	504.0	756.0	1008.0	1260.0	1511.98
31	6.4	1.6	6.7	1.9	3.9	5.8	7.8	59.7	1.66
32	6.3	1.5	6.7	1.9	3.8	5.7	7.6	9.5	1.35
33	6.3	1.5	6.7	1.8	3.7	5.5	7.4	9.2	1.04
34	6.3	1.4	6.6	1.8	3.6	5.4	7.2	8.9	0.73
35	6.2	1.4	6.6	1.7	3.5	5.2	6.9	8.7	0.41
36	176.2	201.3	226.5	251.7	503.4	755.0	1006.7	1258.4	1510.10
37	6.1	1.3	6.5	1.6	3.3	4.9	6.5	8.2	1509.79
38	6.1	1.3	6.4	1.6	3.2	4.7	6.3	7.9	9.47
39	6.1	1.2	6.4	1.5	3.0	4.6	6.1	7.6	9.16
40	6.0	1.2	6.3	1.5	2.9	4.4	5.9	7.4	8.85
41	176.0	201.1	226.3	251.4	502.8	754.3	1005.7	1257.1	1508.53
42	6.0	1.1	6.2	1.4	2.7	4.1	5.5	6.9	8.22
43	5.9	1.1	6.2	1.3	2.6	4.0	5.3	6.6	7.91
44	5.9	1.0	6.1	1.3	2.5	3.8	5.1	6.3	7.59
45	5.8	1.0	6.1	1.2	2.4	3.6	4.8	6.1	7.28
46	175.8	200.9	226.0	251.2	502.3	753.5	1004.6	1255.8	1506.96
47	5.8	0.9	6.0	1.1	2.2	3.3	4.4	5.5	6.65
48	5.7	0.8	5.9	1.1	2.1	3.2	4.2	5.3	6.33
49	5.7	0.8	5.9	1.0	2.0	3.0	4.0	5.0	6.02
50	5.7	0.8	5.9	1.0	1.9	2.9	3.8	4.8	5.71
51	175.6	200.7	225.8	250.9	501.8	752.7	1003.6	1254.5	1505.39
52	5.6	0.7	5.8	0.8	1.7	2.5	3.4	4.2	5.08
53	5.6	0.6	5.7	0.8	1.6	2.4	3.2	4.0	4.76
54	5.5	0.6	5.7	0.7	1.5	2.2	3.0	3.7	4.44
55	5.5	0.6	5.6	0.7	1.4	2.1	2.8	3.4	4.13
56	175.4	200.5	225.6	250.6	501.3	751.9	1002.5	1253.2	1503.81
57	5.4	0.5	5.5	0.6	1.2	1.7	2.3	2.9	3.50
58	5.4	0.4	5.5	0.5	1.1	1.6	2.1	2.6	3.18
59	5.3	0.4	5.4	0.5	1.0	1.4	1.9	2.4	2.86
60	5.3	0.3	5.4	0.4	0.8	1.3	1.7	2.1	2.55

Meridional arcs.	
1′′	30.8
2	61.6
3	92.4
4	123.3
5	154.1
6	184.9
7	215.7
8	246.5
9	277.3
10	308.2
20	616.3
30	924.5
40	1232.6
50	1540.8
1′ 00	1849.0
2	3697.9
3	5546.9
4	7395.9
5	9244.8
6	11093.8
7	12942.8
8	14791.7
9	16640.7
10	18489.7
11	20338.6
12	22187.6

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.1
4	.0	2.0
5	.0	3.2
6	.0	4.6
7	.0	6.3
8	.0	8.2
9	.0	10.3
10	.0	12.8
15	.0	28.7
20	.0	51.1
25	.1	79.8
30	.1	114.9
35	.2	156.4
40	.3	204.3
45	.5	258.6
50	.7	319.2
55	.9	386.3
1° 00	1.2	459.7
1 10	1.8	625.7
1 20	2.8	817.3
1 30	3.9	1034.4
1 40	5.4	1277.0
1 50	7.2	1545.2
2 00	9.3	1838.8

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 36° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	175.3	200.3	225.4	250.4	500.8	751.3	1001.7	1252.1	1502.55
1	5.3	0.3	5.3	0.4	0.7	1.1	1.5	1.9	2.23
2	5.2	0.3	5.3	0.3	0.6	1.0	1.3	1.6	1.92
3	5.2	0.2	5.2	0.3	0.5	0.8	1.1	1.3	1.60
4	5.1	0.2	5.2	0.2	0.4	0.6	0.8	1.1	1.28
5	5.1	0.1	5.1	0.2	0.3	0.5	0.6	0.8	0.97
6	175.1	200.1	225.1	250.1	500.2	750.3	1000.4	1250.5	1500.65
7	5.0	0.0	5.1	0.1	0.1	0.2	0.2	0.3	0.33
8	5.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.02
9	5.0	0.0	5.0	249.9	499.9	49.8	999.8	49.8	1499.70
10	4.9	199.9	4.9	9.9	9.8	9.7	9.6	9.5	9.38
11	174.9	199.9	224.9	249.8	499.7	749.5	999.4	1249.2	1499.06
12	4.9	9.8	4.8	9.8	9.6	9.4	9.2	9.0	8.75
13	4.8	9.8	4.8	9.7	9.5	9.2	9.0	8.7	8.43
14	4.8	9.7	4.7	9.7	9.4	9.1	8.7	8.4	8.11
15	4.7	9.7	4.7	9.6	9.3	8.9	8.5	8.1	7.79
16	174.7	199.7	224.6	249.6	499.2	748.7	998.3	1247.9	1497.47
17	4.7	9.6	4.6	9.5	9.1	8.6	8.1	7.6	7.16
18	4.6	9.6	4.5	9.5	8.9	8.4	7.9	7.4	6.84
19	4.6	9.5	4.5	9.4	8.8	8.3	7.7	7.1	6.52
20	4.6	9.5	4.4	9.4	8.7	8.1	7.5	6.9	6.20
21	174.5	199.5	224.4	249.3	498.6	747.9	997.3	1246.6	1495.88
22	4.5	9.4	4.3	9.3	8.5	7.8	7.0	6.3	5.56
23	4.4	9.4	4.3	9.2	8.4	7.6	6.8	6.0	5.24
24	4.4	9.3	4.2	9.2	8.3	7.5	6.6	5.8	4.92
25	4.4	9.3	4.2	9.1	8.2	7.3	6.4	5.5	4.61
26	174.3	199.2	224.1	249.0	498.1	747.1	996.2	1245.2	1494.29
27	4.3	9.2	4.1	9.0	8.0	7.0	6.0	5.0	3.97
28	4.3	9.2	4.0	8.9	7.9	6.8	5.8	4.7	3.65
29	4.2	9.1	4.0	8.9	7.8	6.7	5.5	4.4	3.33
30	4.2	9.1	4.0	8.8	7.7	6.5	5.3	4.2	3.01

Meridional arcs.	
1″	30.8
2	61.6
3	92.5
4	123.3
5	154.1
6	184.9
7	215.7
8	246.5
9	277.3
10	308.2
20	616.4
30	924.6
40	1232.7
50	1540.9
1′ 00	1849.1
2	3698.2
3	5547.4
4	7396.5
5	9245.6
6	11094.7
7	12943.8
8	14792.9
9	16642.0
10	18491.2
11	20340.3
12	22189.4

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.1
5	.0	3.2
6	.0	4.6
7	.0	6.3
8	.0	8.2
9	.0	10.4
10	.0	12.8
15	.0	28.9
20	.0	51.4
25	.1	80.3
30	.1	115.6
35	.2	157.4
40	.4	205.5
45	.5	260.1
50	.7	321.1
55	.9	388.6
1° 00	1.2	462.4
1 10	1.9	629.4
1 20	2.8	822.1
1 30	4.0	1040.4
1 40	5.5	1284.5
1 50	7.3	1554.3
2 00	9.5	1849.7

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 36° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	174. 2	199. 1	224. 0	248. 8	497. 7	746. 5	995. 3	1244. 2	1493. 01
31	4. 1	9. 0	3. 9	8. 8	7. 6	6. 3	5. 0	3. 9	2. 69
32	4. 1	9. 0	3. 9	8. 7	7. 5	6. 2	4. 9	3. 6	2. 37
33	4. 1	8. 9	3. 9	8. 7	7. 3	6. 0	4. 7	3. 4	2. 05
34	4. 0	8. 9	3. 8	8. 6	7. 2	5. 9	4. 5	3. 1	1. 73
35	4. 0	8. 9	3. 7	8. 6	7. 1	5. 7	4. 3	2. 8	1. 41
36	174. 0	198. 8	223. 7	248. 5	497. 0	745. 5	994. 1	1242. 6	1491. 08
37	3. 9	8. 8	3. 6	8. 5	6. 9	5. 4	3. 8	2. 3	0. 76
38	3. 9	8. 7	3. 6	8. 4	6. 8	5. 2	3. 6	2. 0	0. 44
39	3. 9	8. 7	3. 5	8. 4	6. 7	5. 1	3. 4	1. 8	0. 12
40	3. 8	8. 6	3. 5	8. 3	6. 6	4. 9	3. 2	1. 5	89. 80
41	173. 8	198. 6	223. 4	248. 2	496. 5	744. 7	993. 0	1241. 2	1489. 48
42	3. 7	8. 6	3. 4	8. 2	6. 4	4. 6	2. 8	1. 0	9. 16
43	3. 7	8. 5	3. 3	8. 1	6. 3	4. 4	2. 6	0. 7	8. 84
44	3. 7	8. 5	3. 3	8. 1	6. 2	4. 3	2. 3	0. 4	8. 51
45	3. 6	8. 4	3. 2	8. 0	6. 1	4. 1	2. 1	0. 2	8. 19
46	173. 6	198. 4	223. 2	248. 0	496. 0	743. 9	991. 9	1239. 9	1487. 87
47	3. 6	8. 3	3. 1	7. 9	5. 8	3. 8	1. 7	9. 6	7. 55
48	3. 5	8. 3	3. 1	7. 9	5. 7	3. 6	1. 5	9. 4	7. 23
49	3. 5	8. 3	3. 0	7. 8	5. 6	3. 5	1. 3	9. 1	6. 90
50	3. 4	8. 2	3. 0	7. 8	5. 5	3. 3	1. 1	8. 8	6. 58
51	173. 4	198. 2	222. 9	247. 7	495. 4	743. 1	990. 8	1238. 6	1486. 26
52	3. 4	8. 1	2. 9	7. 7	5. 3	3. 0	0. 6	8. 3	5. 94
53	3. 3	8. 1	2. 8	7. 6	5. 2	2. 8	0. 4	8. 0	5. 61
54	3. 3	8. 0	2. 8	7. 5	5. 1	2. 6	0. 2	7. 7	5. 29
55	3. 3	8 0	2. 7	7. 5	5. 0	2. 5	0. 0	7. 5	4. 97
56	173. 2	198. 0	222. 7	247. 4	494. 9	742. 3	989. 8	1237. 5	1484. 64
57	3. 2	7. 9	2. 6	7. 4	4. 8	2. 2	9. 5	7. 0	4. 32
58	3. 1	7. 9	2. 6	7. 3	4. 7	2. 0	9. 3	6. 7	4. 00
59	3. 1	7. 9	2. 6	7. 3	4. 6	1. 8	9. 1	6. 4	3. 67
60	3. 1	7. 8	2. 5	7. 2	4. 5	1. 7	8. 9	6. 1	3. 35

Meridional arcs.	
1″	30. 8
2	61. 6
3	92. 5
4	123. 3
5	154. 1
6	184. 9
7	215. 7
8	246. 5
9	277. 3
10	308. 2
20	616. 4
30	924. 6
40	1232. 9
50	1541. 1
1′ 00	1849. 3
2	3698. 6
3	5547. 9
4	7397. 1
5	9246. 4
6	11095. 6
7	12944. 9
8	14794. 2
9	16643. 5
10	18492. 8
11	20342. 0
12	22191. 3

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—. 0	. 1
2	. 0	. 5
3	. 0	1. 2
4	. 0	2. 1
5	. 0	3. 2
6	. 0	4. 6
7	. 0	6. 3
8	. 0	8. 3
9	. 0	10. 5
10	. 0	12. 9
15	. 0	29. 1
20	. 0	51. 7
25	. 1	80. 7
30	. 2	116. 2
35	. 2	158. 2
40	. 4	206. 7
45	. 5	261. 5
50	. 7	322. 9
55	. 9	390. 7
1° 00	1. 2	465. 0
1 10	1. 9	632. 9
1 20	2. 9	826. 7
1 30	4. 1	1046. 2
1 40	5. 6	1291. 6
1 50	7. 5	1562. 8
2 00	9. 7	1860. 0

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 37° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)									Meridional arcs.		Co-ordinates of curvature.		
	7″	8″	9″	10″	20″	30″	40″	50″	60″			Minutes of longitude.	X. Arc par.	Y.
0′	173.1	197.8	222.5	247.2	494.5	741.7	988.9	1236.1	1483.35	1″	30.8	1′	—.0	.1
1	3.0	7.7	2.5	7.2	4.3	1.5	8.7	5.9	3.03	2	61.6	2	.0	.5
2	3.0	7.7	2.4	7.1	4.2	1.3	8.5	5.6	2.70	3	92.5	3	.0	1.2
3	3.0	7.7	2.4	7.1	4.1	1.2	8.3	5.3	2.38	4	123.3	4	.0	2.1
4	2.9	7.6	2.3	7.0	4.0	1.0	8.0	5.0	2.05					
5	2.9	7.6	2.3	7.0	3.9	0.9	7.8	4.8	1.73	5	154.1	5	.0	3.2
										6	184.9	6	.0	4.7
6	172.8	197.5	222.2	246.9	493.8	740.7	987.6	1234.5	1481.41	7	215.7	7	.0	6.4
7	2.8	7.5	2.2	6.8	3.7	0.5	7.4	4.2	1.08	8	246.5	8	.0	8.3
8	2.8	7.4	2.1	6.8	3.6	0.4	7.2	4.0	0.76	9	277.3	9	.0	10.5
9	2.7	7.4	2.1	6.7	3.5	0.2	7.0	3.7	0.43					
10	2.7	7.3	2.0	6.7	3.4	0.1	6.7	3.4	0.11	10	308.2	10	.0	13.0
										20	616.4	15	.0	29.2
11	172.6	197.3	222.0	246.6	493.3	739.9	986.5	1233.2	1479.78	30	924.7	20	.0	51.9
12	2.6	7.3	1.9	6.6	3.2	9.7	6.3	2.9	9.46	40	1232.9	25	.1	81.1
13	2.6	7.2	1.9	6.5	3.0	9.6	6.1	2.6	9.13	50	1541.2	30	.2	116.8
14	2.5	7.2	1.8	6.5	2.9	9.4	5.9	2.3	8.81					
15	2.5	7.1	1.8	6.4	2.8	9.2	5.7	2.1	8.48	1′ 00	1849.4	35	.2	159.1
										2	3698.8	40	.4	207.7
16	172.5	197.1	221.7	246.4	492.7	739.1	985.4	1231.8	1478.15	3	5548.2	45	.5	262.9
17	2.4	7.0	1.7	6.3	2.6	8.9	5.2	1.5	7.83	4	7397.6	50	.7	324.6
18	2.4	7.0	1.6	6.2	2.5	8.7	5.0	1.2	7.50	5	9247.1	55	.9	392.8
19	2.3	6.9	1.6	6.2	2.4	8.6	4.8	1.0	7.18	6	11096.6			
20	2.3	6.9	1.5	6.1	2.3	8.4	4.6	0.7	6.85			1° 00	1.2	467.4
										7	12946.0	1 10	1.9	636.2
21	172.3	196.9	221.5	246.1	492.2	738.3	984.4	1230.4	1476.52	8	14795.4	1 20	2.9	831.0
22	2.2	6.8	1.4	6.0	2.1	8.1	4.1	0.2	6.20	9	16644.8	1 30	4.1	1051.8
23	2.2	6.8	1.4	6.0	2.0	7.9	3.9	29.9	5.87	10	18494.3	1 40	5.7	1298.4
24	2.1	6.7	1.3	5.9	1.8	7.8	3.7	9.6	5.54	11	20343.7	1 50	7.6	1571.0
25	2.1	6.7	1.3	5.9	1.7	7.6	3.5	9.4	5.22	12	22193.2	2 00	9.8	1869.7
26	172.1	196.7	221.2	245.8	491.6	737.4	983.3	1229.1	1474.89					
27	2.0	6.6	1.2	5.8	1.5	7.3	3.0	8.8	4.56					
28	2.0	6.6	1.1	5.7	1.4	7.1	2.8	8.5	4.24					
29	2.0	6.5	1.1	5.7	1.3	7.0	2.6	8.3	3.91					
30	171.9	6.5	1.0	5.6	1.2	6.8	2.4	8.0	3.58					

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 37° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	171.9	196.5	221.0	245.6	491.2	736.8	982.4	1228.0	1473.58
31	1.9	6.4	1.0	5.5	1.1	6.6	2.2	7.7	3.25
32	1.8	6.4	0.9	5.5	1.0	6.5	2.0	7.4	2.93
33	1.8	6.3	0.9	5.4	0.9	6.3	1.7	7.2	2.60
34	1.8	6.3	0.8	5.4	0.8	6.1	1.5	6.9	2.27
35	1.7	6.3	0.8	5.3	0.6	6.0	1.3	6.6	1.94
36	171.7	196.2	220.7	245.3	490.5	735.8	981.1	1226.3	1471.61
37	1.6	6.2	0.7	5.2	0.4	5.6	0.9	6.1	1.29
38	1.6	6.1	0.6	5.2	0.3	5.5	0.6	5.8	0.96
39	1.6	6.1	0.6	5.1	0.2	5.3	0.4	5.5	0.63
40	1.5	6.0	0.5	5.0	0.1	5.1	0.2	5.3	0.30
41	171.5	196.0	220.5	245.0	490.0	735.0	980.0	1225.0	1469.97
42	1.5	6.0	0.4	4.9	89.9	4.8	79.8	4.7	9.64
43	1.4	5.9	0.4	4.9	9.8	4.6	9.5	4.4	9.31
44	1.4	5.9	0.3	4.8	9.7	4.5	9.3	4.2	8.98
45	1.3	5.8	0.3	4.8	9.5	4.3	9.1	3.9	8.65
46	171.3	195.8	220.2	244.7	489.4	734.2	978.9	1223.6	1468.32
47	1.3	5.7	0.2	4.7	9.3	4.0	8.7	3.3	8.00
48	1.2	5.7	0.1	4.6	9.2	3.8	8.4	3.1	7.67
49	1.2	5.6	0.1	4.6	9.1	3.7	8.2	2.8	7.34
50	1.2	5.6	0.1	4.5	9.0	3.5	8.0	2.5	7.01
51	171.1	195.6	220.0	244.4	488.9	733.3	977.8	1222.2	1466.68
52	1.1	5.5	0.0	4.4	8.8	3.2	7.6	2.0	6.34
53	1.0	5.5	219.9	4.3	8.7	3.0	7.3	1.7	6.01
54	1.0	5.4	9.9	4.3	8.6	2.8	7.1	1.4	5.68
55	1.0	5.4	9.8	4.2	8.5	2.7	6.9	1.1	5.35
56	170.9	195.3	219.8	244.2	488.3	732.5	976.7	1220.9	1465.02
57	0.9	5.3	9.7	4.1	8.2	2.3	6.5	0.6	4.69
58	0.8	5.2	9.7	4.1	8.1	2.2	6.2	0.3	4.36
59	0.8	5.2	9.6	4.0	8.0	2.0	6.0	0.0	4.03
60	0.8	5.2	9.6	4.0	7.9	1.8	5.8	1219.7	3.70

Meridional arcs.	
1″	30.8
2	61.7
3	92.5
4	123.3
5	154.1
6	185.0
7	215.8
8	246.6
9	277.4
10	308.3
20	616.5
30	924.8
40	1233.1
50	1541.3
1′ 00	1849.6
2	3699.2
3	5548.8
4	7398.4
5	9247.9
6	11097.5
7	12947.1
8	14796.7
9	16646.3
10	18495.9
11	20345.5
12	22195.0

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.1
5	.0	3.3
6	.0	4.7
7	.0	6.4
8	.0	8.4
9	.0	10.6
10	.0	13.0
15	.0	29.4
20	.0	52.2
25	.1	81.5
30	.2	117.4
35	.2	159.8
40	.4	208.8
45	.5	264.2
50	.7	326.2
55	1.0	394.7
1° 00	1.2	469.8
1 10	2.0	639.3
1 20	3.0	835.0
1 30	4.2	1057.2
1 40	5.8	1304.7
1 50	7.7	1578.7
2 00	10.0	1878.8

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 38° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	170.8	195.2	219.6	244.0	487.9	731.8	975.8	1219.7	1463.70
1	0.7	5.1	9.5	3.9	7.8	1.7	5.6	9.5	3.37
2	0.7	5.1	9.5	3.8	7.7	1.5	5.4	9.2	3.04
3	0.7	5.0	9.4	3.8	7.6	1.3	5.1	8.9	2.70
4	0.6	5.0	9.4	3.7	7.5	1.2	4.9	8.6	2.37
5	0.6	4.9	9.3	3.7	7.3	1.0	4.7	8.4	2.04
6	170.5	194.9	219.3	243.6	487.2	730.9	974.5	1218.1	1461.71
7	0.5	4.8	9.2	3.6	7.1	0.7	4.3	7.8	1.38
8	0.5	4.8	9.2	3.5	7.0	0.5	4.0	7.5	1.04
9	0.4	4.8	9.1	3.5	6.9	0.4	3.8	7.3	0.71
10	0.4	4.7	9.1	3.4	6.8	0.2	3.6	7.0	0.38
11	170.3	194.7	219.0	243.3	486.7	730.0	973.4	1216.7	1460.05
12	0.3	4.6	9.0	3.3	6.6	29.9	3.1	6.4	59.71
13	0.3	4.6	8.9	3.2	6.5	9.7	2.9	6.2	9.38
14	0.2	4.5	8.9	3.2	6.3	9.5	2.7	5.9	9.05
15	0.2	4.5	8.8	3.1	6.2	9.4	2.5	5.6	8.72
16	170.1	194.5	218.8	243.1	486.1	729.2	972.3	1215.3	1458.38
17	0.1	4.4	8.7	3.0	6.0	9.0	2.0	5.0	8.05
18	0.1	4.4	8.7	3.0	5.9	8.9	1.8	4.8	7.72
19	0.0	4.3	8.6	2.9	5.8	8.7	1.6	4.5	7.38
20	0.0	4.3	8.6	2.8	5.7	8.5	1.4	4.2	7.05
21	170.0	194.2	218.5	242.8	485.6	728.4	971.1	1213.9	1456.71
22	169.9	4.2	8.5	2.7	5.5	8.2	0.9	3.6	6.38
23	9.9	4.1	8.4	2.7	5.4	8.0	0.7	3.4	6.05
24	9.8	4.1	8.4	2.6	5.2	7.9	0.5	3.1	5.71
25	9.8	4.1	8.3	2.6	5.1	7.7	0.2	2.8	5.38
26	169.8	194.0	218.3	242.5	485.0	727.5	970.0	1212.5	1455.04
27	9.7	4.0	8.2	2.5	4.9	7.4	69.8	2.3	4.71
28	9.7	3.9	8.2	2.4	4.8	7.2	9.6	2.0	4.37
29	9.6	3.9	8.1	2.3	4.7	7.0	9.4	1.7	4.04
30	9.6	3.8	8.1	2.3	4.6	6.9	9.1	1.4	3.71

Meridional arcs.	
1′	30.8
2	61.7
3	92.5
4	123.3
5	154.2
6	185.0
7	215.8
8	246.6
9	277.4
10	308.3
20	616.6
30	924.9
40	1233.2
50	1541.4
1′ 00	1849.7
2	3699.5
3	5549.2
4	7399.0
5	9248.7
6	11098.5
7	12948.2
8	14797.9
9	16647.6
10	18497.4
11	20347.2
12	22196.9

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.1
5	.0	3.3
6	.0	4.7
7	.0	6.4
8	.0	8.4
9	.0	10.6
10	.0	13.1
15	.0	29.5
20	.0	52.4
25	.1	81.9
30	.2	118.0
35	.3	160.6
40	.4	209.7
45	.5	265.4
50	.7	327.7
55	1.0	396.5
1° 00	1.3	471.8
1 10	2.0	642.2
1 20	3.0	838.8
1 30	4.3	1061.6
1 40	5.9	1310.7
1 50	7.8	1585.9
2 00	10.1	1887.4

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 38° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	169.6	193.8	218.1	242.3	484.6	726.9	969.1	1211.4	1453.71
31	9.6	3.8	8.0	2.2	4.5	6.7	8.9	1.1	3.37
32	9.5	3.7	8.0	2.2	4.3	6.5	8.7	0.9	3.03
33	9.5	3.7	7.9	2.1	4.2	6.3	8.5	0.6	2.70
34	9.4	3.6	7.9	2.1	4.1	6.2	8.2	0.3	2.36
35	9.4	3.6	7.8	2.0	4.0	6.0	8.0	0.0	2.03
36	169.4	193.6	217.8	241.9	483.9	725.8	967.8	1209.7	1451.69
37	9.3	3.5	7.7	1.9	3.8	5.7	7.6	9.5	1.36
38	9.3	3.5	7.7	1.8	3.7	5.5	7.3	9.2	1.02
39	9.2	3.4	7.6	1.8	3.6	5.3	7.1	8.9	0.68
40	9.2	3.4	7.6	1.7	3.5	5.2	6.9	8.6	0.35
41	169.2	193.3	217.5	241.7	483.3	725.0	966.7	1208.3	1450.01
42	9.1	3.3	7.5	1.6	3.2	4.8	6.5	8.1	49.68
43	9.1	3.2	7.4	1.6	3.1	4.7	6.2	7.8	9.34
44	9.1	3.2	7.4	1.5	3.0	4.5	6.0	7.5	9.00
45	9.0	3.2	7.3	1.4	2.9	4.3	5.8	7.2	8.67
46	169.0	193.1	217.2	241.4	482.8	724.2	965.6	1206.9	1448.33
47	8.9	3.1	7.2	1.3	2.7	4.0	5.3	6.7	7.99
48	8.9	3.0	7.1	1.3	2.5	3.8	5.1	6.4	7.66
49	8.8	3.0	7.1	1.2	2.4	3.7	4.9	6.1	7.32
50	8.8	2.9	7.0	1.2	2.3	3.5	4.6	5.8	6.98
51	168.8	192.9	217.0	241.1	482.2	723.3	964.4	1205.5	1446.64
52	8.7	2.8	6.9	1.1	2.1	3.2	4.2	5.3	6.31
53	8.7	2.8	6.9	1.0	2.0	3.0	4.0	5.0	5.97
54	8.7	2.8	6.8	0.9	1.9	2.8	3.8	4.7	5.63
55	8.6	2.7	6.8	0.9	1.8	2.6	3.5	4.4	5.29
56	168.6	192.7	216.7	240.8	481.7	722.5	963.3	1204.1	1444.95
57	8.5	2.6	6.7	0.8	1.5	2.3	3.1	3.8	4.62
58	8.5	2.6	6.6	0.7	1.4	2.1	2.9	3.6	4.28
59	8.5	2.5	6.6	0.7	1.3	2.0	2.6	3.3	3.94
60	8.4	2.5	6.5	0.6	1.2	1.8	2.4	3.0	3.60

Meridional arcs.	
1″	30.8
2	61.7
3	92.5
4	123.3
5	154.2
6	185.0
7	215.8
8	246.6
9	277.4
10	308.3
20	616.6
30	924.9
40	1233.2
50	1541.5
1′ 00	1849.9
2	3699.8
3	5549.7
4	7399.6
5	9249.5
6	11099.4
7	12949.3
8	14799.2
9	16649.1
10	18499.0
11	20348.9
12	22198.8

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.1
5	.0	3.3
6	.0	4.7
7	.0	6.4
8	.0	8.4
9	.0	10.7
10	.0	13.2
15	.0	29.6
20	.0	52.8
25	.1	82.3
30	.2	118.5
35	.3	161.2
40	.4	210.6
45	.5	266.5
50	.7	329.0
55	1.0	398.1
1° 00	1.3	473.8
1 10	2.0	644.9
1 20	3.0	842.4
1 30	4.3	1066.1
1 40	6.0	1316.2
1 50	7.9	1592.6
2 00	10.3	1895.3

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 39° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)									Meridional arcs.		Co-ordinates of curvature.		
	7″	8″	9″	10″	20″	30″	40″	50″	60″			Minutes of longitude.	X. Arc par.	Y.
0′	168.4	192.5	216.5	240.6	481.2	721.8	962.4	1203.0	1443.60	1″	30.8	1′	—.0	.1
1	8.4	2.4	6.5	0.5	1.1	1.6	2.2	2.7	3.26	2	61.7	2	.0	.5
2	8.3	2.4	6.4	0.5	1.0	1.5	2.0	2.4	2.92	3	92.5	3	.0	1.2
3	8.3	2.3	6.4	0.4	0.9	1.3	1.7	2.1	2.58	4	123.3	4	.0	2.1
4	8.3	2.3	6.3	0.4	0.7	1.1	1.5	1.9	2.24					
5	8.2	2.3	6.3	0.3	0.6	1.0	1.3	1.6	1.91	5	154.2	5	.0	3.3
										6	185.0	6	.0	4.8
6	168.2	192.2	216.2	240.3	480.5	720.8	961.1	1201.3	1441.57	7	215.8	7	.0	6.5
7	8.1	2.2	6.2	0.2	0.4	0.6	0.8	1.0	1.23	8	246.7	8	.0	8.5
8	8.1	2.1	6.1	0.1	0.3	0.4	0.6	0.7	0.89	9	277.5	9	.0	10.7
9	8.1	2.1	6.1	0.1	0.2	0.3	0.4	0.5	0.55					
10	8.0	2.0	6.0	0.0	0.1	0.1	0.1	0.2	0.21	10	308.3	10	.0	13.2
										20	616.7	15	.0	29.7
11	168.0	192.0	216.0	240.0	480.0	719.9	959.9	1199.9	1439.87	30	925.0	20	.0	52.9
12	7.9	1.9	5.9	239.9	479.8	9.8	9.7	9.6	9.53	40	1233.4	25	.1	82.6
13	7.9	1.9	5.9	9.9	9.7	9.6	9.5	9.3	9.19	50	1541.7	30	.2	118.9
14	7.9	1.8	5.8	9.8	9.6	9.4	9.2	9.0	8.85					
15	7.8	1.8	5.8	9.8	9.5	9.3	9.0	8.8	8.51	1′ 00	1850.1	35	.3	161.9
										2	3700.1	40	.4	211.4
16	167.8	191.8	215.7	239.7	479.4	719.1	958.8	1198.5	1438.17	3	5550.2	45	.6	267.6
17	7.7	1.7	5.7	9.6	9.3	8.9	8.5	8.2	7.82	4	7400.2	50	.8	330.3
18	7.7	1.7	5.6	9.6	9.2	8.7	8.3	7.9	7.48	5	9250.3	55	1.0	399.7
19	7.7	1.6	5.6	9.5	9.0	8.6	8.1	7.6	7.14	6	11100.4			
20	7.6	1.6	5.5	9.5	8.9	8.4	7.9	7.3	6.80			1° 00	1.3	475.7
										7	12950.4	1 10	2.1	647.5
21	167.6	191.5	215.5	239.4	478.8	718.2	957.6	1197.0	1436.46	8	14800.5	1 20	3.1	845.6
22	7.5	1.5	5.4	9.3	8.7	8.1	7.4	6.8	6.12	9	16650.5	1 30	4.4	1070.3
23	7.5	1.4	5.4	9.3	8.6	7.9	7.2	6.5	5.78	10	18500.6	1 40	6.1	1321.3
24	7.5	1.4	5.3	9.2	8.5	7.7	7.0	6.2	5.44	11	20350.7	1 50	8.1	1598.9
25	7.4	1.3	5.3	9.2	8.4	7.5	6.7	5.9	5.10	12	22200.7	2 00	10.4	1902.7
26	167.4	191.3	215.2	239.1	478.2	717.4	956.5	1195.6	1434 75					
27	7.3	1.3	5.2	9.1	8.1	7.2	6.3	5.3	4.41					
28	7.3	1.2	5.1	9.0	8.0	7.0	6.1	5.1	4.07					
29	7.3	1.2	5.1	9.0	7.9	6.9	5.8	4.8	3.73					
30	7.2	1.1	5.0	8.9	7.8	6.7	5.6	4.5	3.38					

TABLE VI.—*Projection Tables*—Continued.

Latitude 39° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	167.2	191.1	215.0	238.9	477.8	716.7	955.6	1194.5	1433.38
31	7.2	1.1	5.0	8.9	7.7	6.5	5.4	4.2	3.04
32	7.1	1.0	4.9	8.8	7.6	6.3	5.1	3.9	2.70
33	7.1	1.0	4.9	8.7	7.5	6.2	4.9	3.6	2.36
34	7.1	0.9	4.8	8.7	7.3	6.0	4.7	3.3	2.00
35	7.0	0.9	4.8	8.6	7.2	5.8	4.4	3.1	1.67
36	167.0	190.8	214.7	238.6	477.1	715.7	954.2	1192.8	1431.33
37	6.9	0.8	4.6	8.5	7.0	5.5	4.0	2.5	0.99
38	6.9	0.8	4.6	8.4	6.9	5.3	3.8	2.2	0.64
39	6.9	0.7	4.5	8.4	6.8	5.1	3.5	1.9	0.30
40	6.8	0.7	4.5	8.3	6.6	5.0	3.3	1.6	29.96
41	166.8	190.6	214.4	238.3	476.5	714.8	953.1	1191.3	1429.61
42	6.7	0.6	4.4	8.2	6.4	4.6	2.9	1.1	9.27
43	6.7	0.5	4.3	8.2	6.3	4.5	2.6	0.8	8.92
44	6.7	0.5	4.3	8.1	6.2	4.3	2.4	0.5	8.58
45	6.6	0.4	4.2	8.0	6.1	4.1	2.2	0.2	8.24
46	166.6	190.4	214.2	238.0	476.0	713.9	951.9	1189.9	1427.89
47	6.5	0.3	4.1	7.9	5.8	3.8	1.7	9.6	7.55
48	6.5	0.3	4.1	7.9	5.7	3.6	1.5	9.3	7.20
49	6.5	0.2	4.0	7.8	5.6	3.4	1.2	9.0	6.86
50	6.4	0.2	4.0	7.8	5.5	3.3	1.0	8.8	6.51
51	166.4	190.2	213.9	237.7	475.4	713.1	950.8	1188.5	1426.17
52	6.3	0.1	3.9	7.6	5.3	2.9	0.6	8.2	5.82
53	6.3	0.1	3.8	7.6	5.2	2.7	0.3	7.9	5.48
54	6.3	0.0	3.8	7.5	5.0	2.6	0.1	7.6	5.13
55	6.2	0.0	3.7	7.5	4.9	2.4	949.9	7.3	4.79
56	166.2	189.9	213.7	237.4	474.8	712.2	949.6	1187.0	1424.44
57	6.1	9.9	3.6	7.4	4.7	2.0	9.4	6.7	4.10
58	6.1	9.8	3.6	7.3	4.6	1.9	9.2	6.5	3.75
59	6.1	9.8	3.5	7.2	4.5	1.7	8.9	6.2	3.41
60	6.0	9.7	3.5	7.2	4.4	1.5	8.7	5.9	3.06

Meridional arcs.	
1″	30.8
2	61.7
3	92.5
4	123.3
5	154.2
6	185.0
7	215.9
8	246.7
9	277.5
10	308.4
20	616.7
30	925.1
40	1233.5
50	1541.8
1′ 00	1850.2
2	3700.4
3	5550.7
4	7400.9
5	9251.1
6	11101.3
7	12951.5
8	14801.7
9	16652.0
10	18502.2
11	20352.4
12	22202.6

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.1
5	.0	3.3
6	.0	4.8
7	.0	6.5
8	.0	8.5
9	.0	10.7
10	.0	13.3
15	.0	29.8
20	.0	53.0
25	.1	82.9
30	.2	119.3
35	.3	162.4
40	.4	212.2
45	.6	268.5
50	.8	331.5
55	1.0	401.1
1° 00	1.3	477.4
1 10	2.1	649.8
1 20	3.1	848.7
1 30	4.5	1074.2
1 40	6.1	1326.1
1 50	8.2	1604.6
2 00	10.6	1909.6

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 40° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.) 7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	166.0	189.7	213.5	237.2	474.4	711.5	948.7	1185.9	1423.06
1	6.0	9.7	3.4	7.1	4.2	1.4	8.5	5.6	2.71
2	5.9	9.6	3.4	7.1	4.1	1.2	8.3	5.3	2.37
3	5.9	9.6	3.3	7.0	4.0	1.0	8.0	5.0	2.02
4	5.9	9.6	3.3	6.9	3.9	0.8	7.8	4.7	1.68
5	5.8	9.5	3.2	6.9	3.8	0.7	7.6	4.4	1.33
6	165.8	189.5	213.1	236.8	473.7	710.5	947.3	1184.1	1420.98
7	5.7	9.4	3.1	6.8	3.5	0.3	7.1	3.9	0.64
8	5.7	9.4	3.0	6.7	3.4	0.1	6.9	3.6	0.29
9	5.7	9.3	3.0	6.7	3.3	0.0	6.6	3.3	19.94
10	5.6	9.3	2.9	6.6	3.2	709.8	6.4	3.0	19.60
11	165.6	189.2	212.9	236.5	473.1	709.6	946.2	1182.7	1419.25
12	5.5	9.2	2.8	6.5	3.0	9.4	5.9	2.4	8.90
13	5.5	9.1	2.8	6.4	2.8	9.3	5.7	2.1	8.55
14	5.5	9.1	2.7	6.4	2.7	9.1	5.5	1.8	8.20
15	5.4	9.0	2.7	6.3	2.6	8.9	5.2	1.5	7.86
16	165.4	189.0	212.6	236.2	472.5	708.8	945.0	1181.3	1417.51
17	5.3	9.0	2.6	6.2	2.4	8.6	4.8	1.0	7.16
18	5.3	8.9	2.5	6.1	2.3	8.4	4.5	0.7	6.81
19	5.3	8.9	2.5	6.1	2.2	8.2	4.3	0.4	6.46
20	5.2	8.8	2.4	6.0	2.0	8.1	4.1	0.1	6.12
21	165.2	188.8	212.4	236.0	471.9	707.9	943.8	1179.8	1415.77
22	5.1	8.7	2.3	5.9	1.8	7.7	3.6	9.5	5.42
23	5.1	8.7	2.3	5.8	1.7	7.5	3.4	9.2	5.07
24	5.1	8.6	2.2	5.8	1.6	7.4	3.2	8.9	4.72
25	5.0	8.6	2.2	5.7	1.5	7.2	2.9	8.6	4.37
26	165.0	188.5	212.1	235.7	471.3	707.0	942.7	1178.4	1414.02
27	4.9	8.5	2.1	5.6	1.2	6.8	2.4	8.1	3.67
28	4.9	8.4	2.0	5.6	1.1	6.7	2.2	7.8	3.32
29	4.8	8.4	1.9	5.5	1.0	6.5	2.0	7.5	2.98
30	4.8	8.3	1.9	5.4	0.8	6.3	1.8	7.2	2.63

Meridional arcs.	
1″	30.8
2	61.7
3	92.5
4	123.4
5	154.2
6	185.0
7	215.9
8	246.7
9	277.6
10	308.4
20	616.8
30	925.2
40	1233.6
50	1542.0
1′ 00	1850.4
2	3700.8
3	5551.1
4	7401.5
5	9251.9
6	11102.3
7	12952.6
8	14803.0
9	16653.4
10	18503.8
11	20354.1
12	22204.5

Co-ordinates of curvature. Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.1
5	.0	3.3
6	.0	4.8
7	.0	6.5
8	.0	8.5
9	.0	10.8
10	.0	13.3
15	.0	29.9
20	.0	53.2
25	.1	83.2
30	.2	119.7
35	.3	163.0
40	.4	212.9
45	.6	269.4
50	.8	332.6
55	1.0	402.5
1° 00	1.3	479.0
1 10	2.1	651.9
1 20	3.2	851.5
1 30	4.5	1077.7
1 40	6.2	1330.5
1 50	8.3	1609.8
2 00	10.7	1915.9

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 40° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	164.8	188.3	211.9	235.4	470.8	706.3	941.8	1177.2	1412.63
31	4.8	8.3	1.8	5.4	0.7	6.1	1.5	6.9	12.28
32	4.7	8.3	1.8	5.3	0.6	6.0	1.3	6.6	11.93
33	4.7	8.2	1.7	5.3	0.5	5.8	1.1	6.3	11.58
34	4.6	8.2	1.7	5.2	0.4	5.6	0.8	6.0	11.23
35	4.6	8.1	1.6	5.1	0.3	5.4	0.6	5.7	10.88
36	164.6	188.1	211.6	235.1	470.2	705.3	940.4	1175.4	1410.53
37	4.5	8.0	1.5	5.0	0.1	5.1	0.1	5.1	10.18
38	4.5	8.0	1.5	5.0	469.9	4.9	39.9	4.9	09.83
39	4.4	7.9	1.4	4.9	9.8	4.7	9.7	4.6	09.48
40	4.4	7.9	1.4	4.8	9.7	4.6	9.4	4.3	09.12
41	164.4	187.8	211.3	234.8	469.6	704.4	939.2	1174.0	1408.77
42	4.3	7.8	1.3	4.7	9.5	4.2	8.9	3.7	8.42
43	4.3	7.7	1.2	4.7	9.4	4.0	8.7	3.4	8.07
44	4.2	7.7	1.2	4.6	9.2	3.9	8.5	3.1	7.72
45	4.2	7.6	1.1	4.6	9.1	3.7	8.2	2.8	7.37
46	164.2	187.6	211.1	234.5	469.0	703.5	938.0	1172.5	1407.02
47	4.1	7.6	1.0	4.4	8.9	3.3	7.8	2.2	6.67
48	4.1	7.5	0.9	4.4	8.8	3.2	7.5	1.9	6.31
49	4.0	7.5	0.9	4.3	8.7	3.0	7.3	1.6	5.96
50	4.0	7.4	0.8	4.3	8.5	2.8	7.1	1.3	5.61
51	163.9	187.4	210.8	234.2	468.4	702.6	936.8	1171.0	1405.26
52	3.9	7.3	0.7	4.2	8.3	2.5	6.6	0.8	4.91
53	3.9	7.3	0.7	4.1	8.2	2.3	6.4	0.5	4.55
54	3.8	7.2	0.6	4.0	8.1	2.1	6.1	0.2	4.20
55	3.8	7.2	0.6	4.0	8.0	1.9	5.9	69.9	3.85
56	163.7	187.1	210.5	233.9	467.8	701.7	935.7	1169.6	1403.50
57	3.7	7.1	0.5	3.8	7.7	1.6	5.4	9.3	3.14
58	3.7	7.0	0.4	3.8	7.6	1.4	5.2	9.0	2.79
59	3.6	7.0	0.4	3.7	7.5	1.2	5.0	8.7	2.44
69	3.6	6.9	0.3	3.7	7.4	1.0	4.7	8.4	2.08

Meridional arcs.	
1″	30.8
2	61.7
3	92.5
4	123.4
5	154.2
6	185.1
7	215.9
8	246.7
9	277.6
10	308.4
20	616.8
30	925.3
40	1233.7
50	1542.1
1′ 00	1850.5
2	3701.1
3	5551.6
4	7402.1
5	9252.7
6	11103.2
7	12953.8
8	14804.3
9	16654.8
10	18505.4
11	20355.9
12	22206.4

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.1
5	.0	3.3
6	.0	4.8
7	.0	6.5
8	.0	8.5
9	.0	10.8
10	.0	13.3
15	.0	30.0
20	.0	53.4
25	.1	83.4
30	.2	120.1
35	.3	163.5
40	.4	213.5
45	.6	270.2
50	.8	333.6
55	1.0	403.6
1° 00	1.3	480.4
1 10	2.1	653.8
1 20	3.2	854.0
1 30	4.6	1080.8
1 40	6.3	1334.3
1 50	8.3	1614.6
2 00	10.8	1921.5

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 41° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	163.6	186.9	210.3	233.7	467.4	701.0	934.7	1168.4	1402.08
1	3.5	6.9	0.3	3.6	7.2	0.9	4.5	8.1	1.73
2	3.5	6.9	0.2	3.6	7.1	0.7	4.3	7.8	1.38
3	3.5	6.8	0.2	3.5	7.0	0.5	4.0	7.5	1.02
4	3.4	6.8	0.1	3.4	6.9	0.3	3.8	7.2	0.67
5	3.4	6.7	0.0	3.4	6.8	0.2	3.5	6.9	0.32
6	163.3	186.7	210.0	233.3	466.7	700.0	933.3	1166.6	1399.96
7	3.3	6.6	209.9	3.3	6.5	699.8	3.1	6.3	9.61
8	3.2	6.6	9.9	3.2	6.4	9.6	2.8	6.0	9.25
9	3.2	6.5	9.8	3.1	6.3	9.4	2.6	5.8	8.90
10	3.2	6.5	9.8	3.1	6.2	9.3	2.4	5.5	8.55
11	163.1	186.4	209.7	233.0	466.1	699.1	932.2	1165.2	1398.19
12	3.1	6.4	9.7	3.0	5.9	8.9	1.9	4.9	7.84
13	3.0	6.3	9.6	2.9	5.8	8.7	1.7	4.6	7.48
14	3.0	6.3	9.6	2.8	5.7	8.6	1.4	4.3	7.13
15	3.0	6.2	9.5	2.8	5.6	8.4	1.2	4.0	6.77
16	162.9	186.2	209.5	232.7	465.5	698.2	931.0	1163.7	1396.42
17	2.9	6.1	9.4	2.7	5.4	8.0	0.7	3.4	6.06
18	2.8	6.1	9.4	2.6	5.2	7.9	0.5	3.1	5.71
19	2.8	6.0	9.3	2.6	5.1	7.7	0.2	2.8	5.35
20	2.7	6.0	9.2	2.5	5.0	7.5	0.0	2.5	5.00
21	162.7	186.0	209.2	232.4	464.9	697.3	929.8	1162.2	1394.64
22	2.7	5.9	9.1	2.4	4.8	7.1	9.5	1.9	4.29
23	2.6	5.9	9.1	2.3	4.6	7.0	9.3	1.6	3.93
24	2.6	5.8	9.0	2.3	4.5	6.8	9.1	1.3	3.57
25	2.5	5.8	9.0	2.2	4.4	6.6	8.8	1.0	3.22
26	162.5	185.7	208.9	232.1	464.3	696.4	928.6	1160.7	1392.86
27	2.5	5.7	8.9	2.1	4.2	6.2	8.3	0.4	2.50
28	2.4	5.6	8.8	2.0	4.0	6.1	8.1	0.1	2.15
29	2.4	5.6	8.8	2.0	3.9	5.9	7.9	1159.8	1.79
30	2.3	5.5	8.7	1.9	3.8	5.7	7.6	9.5	1.43

Meridional arcs.	
1″	30.8
2	61.7
3	92.5
4	123.4
5	154.2
6	185.1
7	215.9
8	246.8
9	277.6
10	308.4
20	616.9
30	925.3
40	1233.8
50	1542.2
1′ 00	1850.7
2	3701.4
3	5552.1
4	7402.8
5	9253.5
6	11104.2
7	12954.9
8	14805.6
9	16656.3
10	18507.0
11	20357.7
12	22208.4

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.1
5	.0	3.3
6	.0	4.8
7	.0	6.6
8	.0	8.6
9	.0	10.8
10	.0	13.4
15	.0	30.1
20	.1	53.5
25	.1	83.6
30	.2	120.4
35	.3	163.9
40	.4	214.1
45	.6	270.9
50	.8	334.5
55	1.1	404.7
1° 00	1.4	481.6
1 10	2.2	655.5
1 20	3.3	856.2
1 30	4.7	1083.7
1 40	6.4	1337.9
1 50	8.5	1618.8
2 00	11.1	1926.5

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 41° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	162.3	185.5	208.7	231.9	463.8	695.7	927.6	1159.5	1391.43
31	2.3	5.5	8.7	1.8	3.7	5.5	7.4	9.2	1.08
32	2.3	5.4	8.6	1.8	3.6	5.4	7.2	8.9	0.72
33	2.2	5.4	8.6	1.7	3.5	5.2	6.9	8.6	0.36
34	2.2	5.3	8.5	1.7	3.3	5.0	6.7	8.3	0.01
35	2.1	5.3	8.4	1.6	3.2	4.8	6.4	8.0	89.65
36	162.1	185.2	208.4	231.5	463.1	694.6	926.2	1157.7	1389.29
37	2.0	5.2	8.3	1.5	3.0	4.5	6.0	7.4	8.93
38	2.0	5.1	8.3	1.4	2.9	4.3	5.7	7.1	8.58
39	2.0	5.1	8.2	1.4	2.7	4.1	5.5	6.8	8.22
40	1.9	5.0	8.2	1.3	2.6	3.9	5.2	6.5	7.86
41	161.9	185.0	208.1	231.2	462.5	693.7	925.0	1156.2	1387.50
42	1.8	5.0	8.1	1.2	2.4	3.6	4.8	6.0	7.15
43	1.8	4.9	8.0	1.1	2.3	3.4	4.5	5.7	6.79
44	1.8	4.9	8.0	1.1	2.1	3.2	4.3	5.4	6.43
45	1.7	4.8	7.9	1.0	2.0	3.0	4.0	5.1	6.07
46	161.7	184.8	207.9	231.0	461.9	692.9	923.8	1154.8	1385.71
47	1.6	4.7	7.8	230.9	1.8	2.7	3.6	4.5	5.35
48	1.6	4.7	7.7	0.8	1.7	2.5	3.3	4.2	4.99
49	1.5	4.6	7.7	0.8	1.5	2.3	3.1	3.9	4.64
50	1.5	4.6	7.6	0.7	1.4	2.1	2.9	3.6	4.28
51	161.4	184.5	207.6	230.6	461.3	692.0	922.6	1153.3	1383.92
52	1.4	4.5	7.5	0.6	1.2	1.8	2.4	3.0	3.56
53	1.4	4.4	7.5	0.5	1.1	1.6	2.1	2.7	3.20
54	1.3	4.4	7.4	0.5	0.9	1.4	1.9	2.4	2.84
55	1.3	4.3	7.4	0.4	0.8	1.2	1.7	2.1	2.48
56	161.2	184.3	207.3	230.3	460.7	691.1	921.4	1151.8	1382.12
57	1.2	4.2	7.3	0.3	0.6	0.9	1.1	1.5	1.76
58	1.2	4.2	7.2	0.2	0.5	0.7	0.9	1.2	1.40
59	1.1	4.1	7.2	0.2	0.3	0.5	0.7	0.9	1.04
60	1.1	4.1	7.1	0.1	0.2	0.3	0.4	0.6	0.68

Meridional arcs.	
1″	30.8
2	61.7
3	92.5
4	123.4
5	154.2
6	185.1
7	215.9
8	246.8
9	277.6
10	308.5
20	617.0
30	925.4
40	1233.9
50	1542.4
1′ 00	1850.9
2	3701.7
3	5552.6
4	7403.4
5	9254.3
6	11105.1
7	12956.0
8	14806.9
9	16657.7
10	18508.6
11	20359.4
12	22210.3

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.1
5	.0	3.4
6	.0	4.8
7	.0	6.6
8	.0	8.6
9	.0	10.9
10	.0	13.4
15	.0	30.2
20	.1	53.6
25	.1	83.8
30	.2	120.7
35	.3	164.3
40	.4	214.5
45	.6	271.5
50	.8	335.2
55	1.1	405.7
1° 00	1.4	482.8
1 10	2.2	657.1
1 20	3.3	858.2
1 30	4.7	1086.2
1 40	6.5	1341.0
1 50	8.6	1622.6
2 00	11.2	1931.1

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 42° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	161.1	184.1	207.1	230.1	460.2	690.3	920.4	1150.6	1380.68
1	1.0	4.0	7.0	0.1	0.1	0.2	0.2	0.3	0.32
2	1.0	4.0	7.0	0.0	0.0	0.0	0.0	0.0	79.96
3	1.0	3.9	6.9	29.9	59.9	689.8	919.7	49.7	9.60
4	0.9	3.9	6.9	9.9	9.7	9.6	9.5	9.4	9.24
5	0.9	3.9	6.8	9.8	9.6	9.4	9.2	9.1	8.88
6	160.8	183.8	206.8	229.7	459.5	689.3	919.0	1148.8	1378.52
7	0.8	3.8	6.7	9.7	9.4	9.1	8.8	8.5	8.15
8	0.7	3.7	6.7	9.6	9.3	8.9	8.5	8.2	7.79
9	0.7	3.7	6.6	9.6	9.1	8.7	8.3	7.9	7.43
10	0.7	3.6	6.6	9.5	9.0	8.5	8.0	7.6	7.07
11	160.6	183.6	206.5	229.5	458.9	688.4	917.8	1147.3	1376.71
12	0.6	3.5	6.5	9.4	8.8	8.2	7.6	7.0	6.35
13	0.5	3.5	6.4	9.3	8.7	8.0	7.3	6.7	5.99
14	0.5	3.4	6.3	9.3	8.5	7.8	7.1	6.3	5.62
15	0.4	3.4	6.3	9.2	8.4	7.6	6.8	6.0	5.26
16	160.4	183.3	206.2	229.1	458.3	687.4	916.6	1145.7	1374.90
17	0.4	3.3	6.2	9.1	8.2	7.3	6.4	5.4	4.54
18	0.3	3.2	6.1	9.0	8.1	7.1	6.1	5.1	4.17
19	0.3	3.2	6.1	9.0	7.9	6.9	5.9	4.8	3.81
20	0.2	3.1	6.0	8.9	7.8	6.7	5.6	4.5	3.45
21	160.2	183.1	206.0	228.9	457.7	686.5	915.4	1144.2	1373.09
22	0.2	3.0	5.9	8.8	7.6	6.4	5.1	3.9	2.72
23	0.1	3.0	5.9	8.7	7.5	6.2	4.9	3.6	2.36
24	0.1	2.9	5.8	8.7	7.3	6.0	4.7	3.3	2.00
25	0.0	2.9	5.7	8.6	7.2	5.8	4.4	3.0	1.64
26	160.0	182.8	205.7	228.5	457.1	685.6	914.2	1142.7	1371.27
27	159.9	2.8	5.6	8.5	7.0	5.5	3.9	2.4	0.91
28	9.9	2.7	5.6	8.4	6.8	5.3	3.7	2.1	0.55
29	9.9	2.7	5.5	8.4	6.7	5.1	3.5	1.8	0.18
30	9.8	2.6	5.5	8.3	6.6	4.9	3.2	1.5	1369.82

Meridional arcs.	
1″	30.9
2	61.7
3	92.6
4	123.4
5	154.3
6	185.1
7	216.0
8	246.8
9	277.7
10	308.5
20	617.0
30	925.5
40	1234.0
50	1542.5
1′ 00	1851.0
2	3702.0
3	5553.1
4	7404.1
5	9255.1
6	11106.1
7	12957.1
8	14808.2
9	16659.2
10	18510.2
11	20361.2
12	22212.2

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.1
5	.0	3.4
6	.0	4.8
7	.0	6.6
8	.0	8.6
9	.0	10.9
10	.0	13.4
15	.0	30.4
20	.1	53.7
25	.1	84.0
30	.2	120.9
35	.3	164.6
40	.4	215.0
45	.6	272.1
50	.8	335.9
55	1.1	406.4
1° 00	1.4	483.7
1 10	2.2	658.4
1 20	3.3	860.0
1 30	4.8	1088.3
1 40	6.5	1343.7
1 50	8.7	1625.8
2 00	11.3	1934.9

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 42° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.) 7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	159.8	182.6	205.5	228.3	456.6	684.9	913.2	1141.5	1369.82
31	9.8	2.6	5.4	8.2	6.5	4.7	3.0	1.2	9.45
32	9.7	2.5	5.4	8.2	6.4	4.5	2.7	0.9	9.09
33	9.7	2.5	5.3	8.1	6.2	4.4	2.5	0.6	8.73
34	9.6	2.4	5.3	8.1	6.1	4.2	2.2	0.3	8.36
35	9.6	2.4	5.2	8.0	6.0	4.0	2.0	0.0	8.00
36	159.6	182.4	205.2	227.9	455.9	683.8	911.8	1139.7	1367.63
37	9.5	2.3	5.1	7.9	5.8	3.6	1.5	9.4	7.27
38	9.5	2.3	5.0	7.8	5.6	3.5	1.3	9.1	6.90
39	9.4	2.2	5.0	7.8	5.5	3.3	1.0	8.8	6.54
40	9.4	2.2	4.9	7.7	5.4	3.1	0.8	8.5	6.17
41	159.3	182.1	204.9	227.6	455.3	682.9	910.5	1138.2	1365.81
42	9.3	2.1	4.8	7.6	5.1	2.7	0.3	7.9	5.44
43	9.3	2.0	4.8	7.5	5.0	2.5	0.0	7.6	5.08
44	9.2	2.0	4.7	7.5	4.9	2.4	909.8	7.3	4.71
45	9.2	1.9	4.7	7.4	4.8	2.2	9.6	7.0	4.35
46	159.1	181.9	204.6	227.3	454.7	682.0	909.3	1136.6	1363.98
47	9.1	1.8	4.5	7.3	4.5	1.8	9.1	6.3	3.62
48	9.0	1.8	4.5	7.2	4.4	1.6	8.8	6.0	3.25
49	9.0	1.7	4.4	7.1	4.3	1.4	8.6	5.7	2.88
50	9.0	1.7	4.4	7.1	4.2	1.3	8.3	5.4	2.52
51	158.9	181.6	204.3	227.0	454.0	681.1	908.1	1135.1	1362.15
52	8.9	1.6	4.3	7.0	3.9	0.9	7.9	4.8	1.79
53	8.8	1.5	4.2	6.9	3.8	0.7	7.6	4.5	1.42
54	8.8	1.5	4.2	6.8	3.7	0.5	7.4	4.2	1.05
55	8.7	1.4	4.1	6.8	3.6	0.3	7.1	3.9	0.69
56	158.7	181.4	204.0	226.7	453.4	680.2	906.9	1133.6	1360.32
57	8.7	1.3	4.0	6.7	3.3	0.0	6.6	3.3	59.95
58	8.6	1.3	3.9	6.6	3.2	79.8	6.4	3.0	9.59
59	8.6	1.2	3.9	6.5	3.1	9.6	6.1	2.7	9.22
60	8.5	1.2	3.8	6.5	3.0	9.4	5.9	2.4	8.85

Meridional arcs.	
1″	30.9
2	61.7
3	92.6
4	123.4
5	154.3
6	185.1
7	216.0
8	246.8
9	277.7
10	308.5
20	617.1
30	925.6
40	1234.1
50	1542.7
1′ 00	1851.2
2	3702.4
3	5553.5
4	7404.7
5	9255.9
6	11107.1
7	12958.3
8	14809.4
9	16660.6
10	18511.8
11	20363.0
12	22214.2

Co-ordinates of curvature. Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.2
5	.0	3.4
6	.0	4.8
7	.0	6.6
8	.0	8.6
9	.0	10.9
10	.0	13.5
15	.0	30.4
20	.1	53.8
25	.1	84.1
30	.2	121.1
35	.3	164.9
40	.4	215.4
45	.6	272.5
50	.8	336.5
55	1.1	407.1
1° 00	1.4	484.6
1 10	2.3	659.5
1 20	3.4	861.4
1 30	4.8	1090.2
1 40	6.6	1346.0
1 50	8.8	1628.6
2 00	11.4	1938.2

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 43° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	158.5	181.2	203.8	226.5	453.0	679.4	905.9	1132.4	1358.85
1	8.5	1.1	3.8	6.4	2.8	9.2	5.7	2.1	8.48
2	8.4	1.1	3.7	6.3	2.7	9.1	5.4	1.8	8.12
3	8.4	1.0	3.7	6.3	2.6	8.9	5.2	1.5	7.75
4	8.4	1.0	3.6	6.2	2.5	8.7	4.9	1.2	7.38
5	8.3	0.9	3.6	6.2	2.3	8.5	4.7	0.8	7.02
6	158.3	180.9	203.5	226.1	452.2	678.3	904.4	1130.5	1356.65
7	8.2	0.8	3.4	6.0	2.1	8.1	4.2	0.2	6.28
8	8.2	0.8	3.4	6.0	2.0	8.0	3.9	29.9	5.91
9	8.1	0.7	3.3	5.9	1.8	7.8	3.7	9.6	5.54
10	8.1	0.7	3.3	5.9	1.7	7.6	3.4	9.3	5.17
11	158.1	180.6	203.2	225.8	451.6	677.4	903.2	1129.0	1354.81
12	8.0	0.6	3.2	5.7	1.5	7.2	3.0	8.7	4.44
13	8.0	0.5	3.1	5.7	1.4	7.0	2.7	8.4	4.07
14	7.9	0.5	3.1	5.6	1.2	6.8	2.5	8.1	3.70
15	7.9	0.4	3.0	5.6	1.1	6.7	2.2	7.8	3.33
16	157.8	180.4	302.9	225.5	451.0	676.5	902.0	1127.5	1352.96
17	7.8	0.3	2.9	5.4	0.9	6.3	1.7	7.2	2.59
18	7.8	0.3	2.8	5.4	0.7	6.1	1.5	6.9	2.22
19	7.7	0.2	2.8	5.3	0.6	5.9	1.2	6.5	1.85
20	7.7	0.2	2.7	5.2	0.5	5.7	1.0	6.2	1.48
21	157.6	180.1	202.7	225.2	450.4	675.6	900.7	1125.9	1351.11
22	7.6	0.1	2.6	5.1	0.2	5.4	0.5	5.6	0.74
23	7.5	0.0	2.6	5.1	0.1	5.2	0.2	5.3	0.37
24	7.5	0.0	2.5	5.0	0.0	5.0	0.0	5.0	0.00
25	7.5	0.0	2.4	4.9	449.9	4.8	899.8	4.7	49.63
26	157.4	179.9	202.4	224.9	449.8	674.6	899.5	1124.4	1349.26
27	7.4	9.9	2.3	4.8	9.6	4.4	9.3	4.1	8.89
28	7.3	9.8	2.3	4.8	9.5	4.3	9.0	3.8	8.52
29	7.3	9.8	2.2	4.7	9.4	4.1	8.8	3.5	8.15
30	7.2	9.7	2.2	4.6	9.3	3.9	8.5	3.1	7.78

Meridional arcs.	
1″	30.9
2	61.7
3	92.6
4	123.4
5	154.3
6	185.1
7	216.0
8	246.8
9	277.7
10	308.6
20	617.1
30	925.7
40	1234.2
50	1542.8
1′ 00	1851.3
2	3702.7
3	5554.0
4	7405.4
5	9256.7
6	11108.1
7	12959.4
8	14810.7
9	16662.1
10	18513.4
11	20364.8
12	22216.1

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.2
5	.0	3.4
6	.0	4.9
7	.0	6.6
8	.0	8.6
9	.0	10.9
10	.0	13.5
15	.0	30.4
20	.1	53.9
25	.1	84.2
30	.2	121.3
35	.3	165.1
40	.4	215.6
45	.6	273.0
50	.8	337.0
55	1.1	407.8
1° 00	1.4	485.2
1 10	2.3	660.5
1 20	3.4	862.6
1 30	4.9	1091.8
1 40	6.7	1347.9
1 50	8.9	1630.9
2 00	11.6	1940.9

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 43° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	157.2	179.7	202.2	224.6	449.3	673.9	898.5	1123.1	1347.78
31	7.2	9.7	2.1	4.6	9.1	3.7	8.3	2.8	7.41
32	7.2	9.6	2.1	4.5	9.0	3.5	8.0	2.5	7.04
33	7.1	9.6	2.0	4.4	8.9	3.3	7.8	2.2	6.67
34	7.1	9.5	1.9	4.4	8.8	3.1	7.5	1.9	6.30
35	7.0	9.5	1.9	4.3	8.6	3.0	7.3	1.6	5.93
36	157.0	179.4	201.8	224.3	448.5	672.8	897.0	1121.3	1345.56
37	6.9	9.4	1.8	4.2	8.4	2.6	6.8	1.0	5.18
38	6.9	9.3	1.7	4.1	8.3	2.4	6.5	0.7	4.81
39	6.9	9.3	1.7	4.1	8.1	2.2	6.3	0.4	4.44
40	6.8	9.2	1.6	4.0	8.0	2.0	6.0	0.1	4.07
41	156.8	179.2	201.6	224.0	447.9	671.8	895.8	1119.7	1343.70
42	6.7	9.1	1.5	3.9	7.8	1.7	5.5	9.4	3.32
43	6.7	9.1	1.4	3.9	7.7	1.5	5.3	9.1	2.95
44	6.6	9.0	1.4	3.8	7.5	1.3	5.1	8.8	2.58
45	6.6	9.0	1.3	3.7	7.4	1.1	4.8	8.5	2.21
46	156.5	178.9	201.3	223.6	447.3	670.9	894.6	1118.2	1341.84
47	6.5	8.9	1.2	3.6	7.2	0.7	4.3	7.9	1.46
48	6.5	8.8	1.2	3.5	7.0	0.5	4.1	7.6	1.09
49	6.4	8.8	1.1	3.5	6.9	0.4	3.8	7.3	0.72
50	6.4	8.7	1.1	3.4	6.8	0.2	3.6	7.0	0.34
51	156.3	178.7	201.0	223.3	446.6	670.0	893.3	1116.6	1339.97
52	6.3	8.6	0.9	3.3	6.5	69.8	3.1	6.3	9.60
53	6.2	8.6	0.9	3.2	6.4	9.6	2.8	6.0	9.22
54	6.2	8.5	0.8	3.1	6.3	9.4	2.6	5.7	8.85
55	6.2	8.5	0.8	3.1	6.2	9.2	2.3	5.4	8.48
56	156.1	178.4	200.7	223.0	446.0	669.0	892.1	1115.1	1338.10
57	6.1	8.4	0.7	2.9	5.9	8.9	1.8	4.8	7.73
58	6.0	8.3	0.6	2.9	5.8	8.7	1.6	4.5	7.36
59	6.0	8.3	0.5	2.8	5.7	8.5	1.3	4.1	6.98
60	5.9	8.2	0.5	2.8	5.5	8.3	1.1	3.8	6.61

Meridional arcs.		
	1″	30.9
	2	61.7
	3	92.6
	4	123.4
	5	154.3
	6	185.2
	7	216.0
	8	246.9
	9	277.7
	10	308.6
	20	617.2
	30	925.8
	40	1234.3
	50	1542.9
1′	00	1851.5
2		3703.0
3		5554.5
4		7406.0
5		9257.5
6		11109.0
7		12960.5
8		14812.0
9		16663.5
10		18515.0
11		20366.5
12		22218.0

Co-ordinates of curvature.			
Minutes of longitude.		X. Arc par.	Y.
	1′	—.0	.1
	2	.0	.5
	3	.0	1.2
	4	.0	2.2
	5	.0	3.4
	6	.0	4.9
	7	.0	6.6
	8	.0	8.6
	9	.0	10.9
	10	.0	13.5
	15	.0	30.4
	20	.1	54.0
	25	.1	84.3
	30	.2	121.4
	35	.3	165.3
	40	.4	215.9
	45	.6	273.3
	50	.8	337.3
	55	1.1	408.2
1°	00	1.5	485.8
1	10	2.3	661.2
1	20	3.5	863.6
1	30	4.9	1093.0
1	40	6.8	1349.4
1	50	9.0	1632.8
2	00	11.7	1943.1

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 44° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)									Meridional arcs.		Co-ordinates of curvature.		
	7″	8″	9″	10″	20″	30″	40″	50″	60″			Minutes of longitude.	X. Arc par.	Y.
0′	155.9	178.2	200.5	222.8	445.5	668.3	891.1	1113.8	1336.61	1″	30.9	1′	—.0	.1
1	5.9	8.2	0.4	2.7	5.4	8.1	0.8	3.5	6.23	2	61.7	2	.0	.5
2	5.8	8.1	0.4	2.6	5.3	7.9	0.6	3.2	5.86	3	92.6	3	.0	1.2
3	5.8	8.1	0.3	2.6	5.2	7.7	0.3	2.9	5.48	4	123.4	4	.0	2.2
4	5.8	8.0	0.3	2.5	5.0	7.6	0.1	2.6	5.11					
5	5.7	8.0	0.2	2.5	4.9	7.4	889.8	2.3	4.74	5	154.3	5	.0	3.4
										6	185.2	6	.0	4.9
6	155.7	177.9	200.2	222.4	444.8	667.2	889.6	1112.0	1334.36	7	216.0	7	.0	6.6
7	5.6	7.9	0.1	2.3	4.7	7.0	9.3	1.7	3.99	8	246.9	8	.0	8.6
8	5.6	7.8	0.0	2.3	4.5	6.8	9.1	1.3	3.61	9	277.8	9	.0	10.9
9	5.5	7.8	0.0	2.2	4.4	6.6	8.8	1.0	3.24					
10	5.5	7.7	199.9	2.1	4.3	6.4	8.6	0.7	2.86	10	308.6	10	.0	13.5
										20	617.2	15	.0	30.4
11	155.5	177.7	199.9	222.1	444.2	666.2	888.3	1110.4	1332.49	30	925.8	20	.1	54.0
12	5.4	7.6	9.8	2.0	4.0	6.1	8.1	0.1	2.11	40	1234.4	25	.1	84.4
13	5.4	7.6	9.8	2.0	3.9	5.9	7.8	1109.8	1.73	50	1543.1	30	.2	121.5
14	5.3	7.5	9.7	1.9	3.8	5.7	7.6	9.5	1.36					
15	5.3	7.5	9.6	1.8	3.7	5.5	7.3	9.2	0.98	1′ 00	1851.7	35	.3	165.4
										2	3703.3	40	.4	216.1
16	155.2	177.4	199.6	221.8	443.5	665.3	887.1	1108.8	1330.61	3	5555.0	45	.6	273.5
17	5.2	7.4	9.5	1.7	3.4	5.1	6.8	8.5	0.23	4	7406.7	50	.9	337.6
18	5.1	7.3	9.5	1.6	3.3	4.9	6.6	8.2	29.85	5	9258.3	55	1.1	408.5
19	5.1	7.3	9.4	1.6	3.2	4.7	6.3	7.9	9.48	6	11110.0			
20	5.1	7.2	9.4	1.5	3.0	4.5	6.1	7.6	9.10			1° 00	1.5	486.1
										7	12961.7	1 10	2.3	661.7
21	155.0	177.2	199.3	221.5	442.9	664.4	885.8	1107.3	1328.73	8	14813.3	1 20	3.5	864.3
22	5.0	7.1	9.3	1.4	2.8	4.2	5.6	7.0	8.35	9	16665.0	1 30	4.9	1093.9
23	4.9	7.1	9.2	1.3	2.7	4.0	5.3	6.6	7.97	10	18516.7	1 40	6.8	1350.4
24	4.9	7.0	9.1	1.3	2.5	3.8	5.1	6.3	7.60	11	20368.3	1 50	9.1	1634.0
25	4.8	7.0	9.1	1.2	2.4	3.6	4.8	6.0	7.22	12	22220.0	2 00	11.8	1944.6
26	154.8	176.9	199.0	221.1	442.3	663.4	884.6	1105.7	1326.84					
27	4.8	6.9	9.0	1.1	2.2	3.2	4.3	5.4	6.46					
28	4.7	6.8	8.9	1.0	2.0	3.0	4.1	5.1	6.09					
29	4.7	6.8	8.9	1.0	1.9	2.9	3.9	4.8	5.71					
30	4.6	6.7	8.8	220.9	1.8	2.7	3.6	4.4	5.33					

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 44° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	154.6	176.7	198.8	220.9	441.8	662.7	883.6	1104.4	1325.33
31	4.6	6.7	8.7	0.8	1.6	2.5	3.3	4.1	4.95
32	4.5	6.6	8.7	0.8	1.5	2.3	3.1	3.8	4.58
33	4.5	6.6	8.6	0.7	1.4	2.1	2.8	3.5	4.20
34	4.4	6.5	8.6	0.6	1.3	1.9	2.5	3.2	3.82
35	4.4	6.5	8.5	0.6	1.1	1.7	2.3	2.9	3.44
36	154.4	176.4	198.5	220.5	441.0	661.5	882.0	1102.5	1323.06
37	4.3	6.4	8.4	0.4	0.9	1.3	1.8	2.2	2.69
38	4.3	6.3	8.3	0.4	0.8	1.2	1.5	1.9	2.31
39	4.2	6.3	8.3	0.3	0.6	1.0	1.3	1.6	1.93
40	4.2	6.2	8.2	0.3	0.5	0.8	1.0	1.3	1.55
41	154.1	176.2	198.2	220.2	440.4	660.6	880.8	1101.0	1321.17
42	4.1	6.1	8.1	0.1	0.3	0.4	0.5	0.7	0.79
43	4.0	6.1	8.1	0.1	0.1	0.2	0.3	0.3	0.41
44	4.0	6.0	8.0	0.0	0.0	0.0	0.0	0.0	0.04
45	4.0	6.0	7.9	219.9	39.9	59.8	79.8	1099.7	19.66
46	153.9	175.9	197.9	219.9	439.8	659.6	879.5	1099.4	1319.28
47	3.9	5.9	7.8	9.8	9.6	9.5	9.3	9.1	8.90
48	3.8	5.8	7.8	9.8	9.5	9.3	9.0	8.8	8.52
49	3.8	5.8	7.7	9.7	9.4	9.1	8.8	8.4	8.14
50	3.7	5.7	7.7	9.6	9.2	8.9	8.5	8.1	7.76
51	153.7	175.7	197.6	219.6	439.1	658.7	878.3	1097.8	1317.38
52	3.6	5.6	7.5	9.5	9.0	8.5	8.0	7.5	7.00
53	3.6	5.5	7.5	9.4	8.9	8.3	7.7	7.2	6.62
54	3.6	5.5	7.4	9.4	8.8	8.1	7.5	6.9	6.24
55	3.5	5.4	7.4	9.3	8.6	7.9	7.2	6.5	5.86
56	153.5	175.4	197.3	219.2	438.5	657.7	877.0	1096.2	1315.48
57	3.4	5.3	7.3	9.2	8.4	7.5	6.7	5.9	5.10
58	3.4	5.3	7.2	9.1	8.2	7.4	6.5	5.6	4.72
59	3.3	5.2	7.1	9.1	8.1	7.2	6.2	5.3	4.34
60	3.3	5.2	7.1	9.0	8.0	7.0	6.0	5.0	3.96

Meridional arcs.	
1″	30.9
2	61.7
3	92.6
4	123.5
5	154.3
6	185.2
7	216.0
8	246.9
9	277.8
10	308.6
20	617.3
30	925.9
40	1234.6
50	1543.2
1′ 00	1851.8
2	3703.7
3	5555.5
4	7407.3
5	9259.1
6	11111.0
7	12962.8
8	14814.6
9	16666.5
10	18518.3
11	20370.1
12	22222.0

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.2
5	.0	3.4
6	.0	4.9
7	.0	6.6
8	.0	8.6
9	.0	10.9
10	.0	13.5
15	.0	30.4
20	.1	54.0
25	.1	84.4
30	.2	121.6
35	.3	165.5
40	.4	216.2
45	.6	273.6
50	.9	337.8
55	1.1	408.7
1° 00	1.5	486.4
1 10	2.4	662.0
1 20	3.5	864.7
1 30	5.1	1094.4
1 40	6.9	1351.1
1 50	9.2	1634.8
2 00	11.9	1945.6

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 45° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	153.3	175.2	197.1	219.0	438.0	657.0	876.0	1095.0	1313.96
1	3.2	5.1	7.0	8.9	7.9	6.8	5.7	4.6	3.57
2	3.2	5.1	7.0	8.9	7.7	6.6	5.5	4.3	3.19
3	3.2	5.0	6.9	8.8	7.6	6.4	5.2	4.0	2.81
4	3.1	5.0	6.9	8.7	7.5	6.2	5.0	3.7	2.43
5	3.1	4.9	6.8	8.7	7.3	6.0	4.7	3.4	2.05
6	153.0	174.9	196.8	218.6	437.2	655.8	874.4	1093.1	1311.67
7	3.0	4.8	6.7	8.5	7.1	5.6	4.2	2.7	1.29
8	2.9	4.8	6.6	8.5	7.0	5.4	3.9	2.4	0.90
9	2.9	4.7	6.6	8.4	6.8	5.3	3.7	2.1	0.52
10	2.9	4.7	6.5	8.4	6.7	5.1	3.4	1.8	0.14
11	152.8	174.6	196.5	218.3	436.6	654.9	873.2	1091.5	1309.76
12	2.8	4.6	6.4	8.2	6.5	4.7	2.9	1.1	9.38
13	2.7	4.5	6.3	8.2	6.3	4.5	2.7	0.8	8.99
14	2.7	4.5	6.3	8.1	6.2	4.3	2.4	0.5	8.61
15	2.6	4.4	6.2	8.0	6.1	4.1	2.2	0.2	8.23
16	152.6	174.4	196.2	218.0	436.0	653.9	871.9	1089.9	1307.85
17	2.5	4.3	6.1	7.9	5.8	3.7	1.6	9.5	7.46
18	2.5	4.3	6.1	7.8	5.7	3.5	1.4	9.2	7.08
19	2.4	4.2	6.0	7.8	5.6	3.3	1.1	8.9	6.70
20	2.4	4.2	5.9	7.7	5.4	3.2	0.9	8.6	6.31
21	152.4	174.1	195.9	217.6	435.3	653.0	870.6	1088.3	1305.93
22	2.3	4.1	5.8	7.6	5.2	2.8	0.4	8.0	5.54
23	2.3	4.0	5.8	7.5	5.1	2.6	0.1	7.6	5.16
24	2.2	4.0	5.7	7.5	4.9	2.4	869.9	7.3	4.78
25	2.2	3.9	5.7	7.4	4.8	2.2	9.6	7.0	4.40
26	152.1	173.9	195.6	217.3	434.7	652.0	869.3	1086.7	1304.01
27	2.1	3.8	5.5	7.3	4.5	1.8	9.1	6.4	3.63
28	2.0	3.8	5.5	7.2	4.4	1.6	8.8	6.0	3.25
29	2.0	3.7	5.4	7.1	4.3	1.4	8.6	5.7	2.86
30	2.0	3.7	5.4	7.1	4.2	1.2	8.3	5.4	2.48

Meridional arcs.	
1″	30.9
2	61.7
3	92.6
4	123.5
5	154.3
6	185.2
7	216.1
8	246.9
9	277.8
10	308.7
20	617.3
30	926.0
40	1234.7
50	1543.3
1′ 00	1852.0
2	3704.0
3	5556.0
4	7408.0
5	9260.0
6	11111.9
7	12963.9
8	14815.9
9	16667.9
10	18519.9
11	20371.9
12	22223.9

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.2
5	.0	3.4
6	.0	4.9
7	.0	6.6
8	.0	8.6
9	.0	10.9
10	.0	13.5
15	.0	30.4
20	.1	54.0
25	.1	84.5
30	.2	121.6
35	.3	165.5
40	.4	216.2
45	.6	273.7
50	.9	337.8
55	1.2	408.8
1° 00	1.5	486.4
1 10	2.4	662.2
1 20	3.6	864.8
1 30	5.1	1094.6
1 40	6.9	1351.3
1 50	9.3	1635.1
2 00	11.9	1945.9

TABLE VI.—*Projection Tables*—Continued.

Latitude 45° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.) 7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	152.0	173.7	195.4	217.1	434.2	651.2	868.3	1085.4	1302.48
31	1.9	3.6	5.3	7.0	4.0	1.0	8.1	5.1	2.09
32	1.9	3.6	5.3	7.0	3.9	0.9	7.8	4.8	1.71
33	1.8	3.5	5.2	6.9	3.8	0.7	7.5	4.4	1.32
34	1.8	3.5	5.1	6.8	3.6	0.5	7.3	4.1	0.94
35	1.7	3.4	5.1	6.8	3.5	0.3	7.0	3.8	0.55
36	151.7	173.4	195.0	216.7	433.4	650.1	866.8	1083.5	1300.17
37	1.6	3.3	5.0	6.6	3.3	49.9	6.5	3.1	1299.78
38	1.6	3.3	4.9	6.6	3.1	9.7	6.3	2.8	9.39
39	1.6	3.2	4.9	6.5	3.0	9.5	6.0	2.5	9.01
40	1.5	3.2	4.8	6.4	2.9	9.3	5.8	2.2	8.63
41	151.5	173.1	194.7	216.4	432.7	649.1	865.5	1081.9	1298.24
42	1.4	3.0	4.7	6.3	2.6	8.9	5.2	1.6	7.86
43	1.4	3.0	4.6	6.2	2.5	8.7	5.0	1.2	7.47
44	1.3	2.9	4.6	6.2	2.4	8.5	4.7	0.9	7.09
45	1.3	2.9	4.5	6.1	2.2	8.3	4.5	0.6	6.70
46	151.2	172.8	194.4	216.1	432.1	648.2	864.2	1080.2	1296.31
47	1.2	2.8	4.4	6.0	2.0	8.0	4.0	1079.9	5.93
48	1.1	2.7	4.3	5.9	1.8	7.8	3.7	9.6	5.54
49	1.1	2.7	4.3	5.9	1.7	7.6	3.4	9.3	5.16
50	1.1	2.6	4.2	5.8	1.6	7.4	3.2	9.0	4.77
51	151.0	172.6	194.2	215.7	431.5	647.2	862.9	1078.7	1294.38
52	1.0	2.5	4.1	5.7	1.3	7.0	2.7	8.3	4.00
53	0.9	2.5	4.0	5.6	1.2	6.8	2.4	8.0	3.61
54	0.9	2.4	4.0	5.5	1.1	6.6	2.1	7.7	3.22
55	0.8	2.4	3.9	5.5	0.9	6.4	1.9	7.3	2.83
56	150.8	172.3	193.9	215.4	430.8	646.2	861.6	1077.0	1292.45
57	0.7	2.3	3.8	5.3	0.7	6.0	1.4	6.7	2.06
58	0.7	2.2	3.8	5.3	0.6	5.8	1.1	6.4	1.67
59	0.6	2.2	3.7	5.2	0.4	5.6	0.9	6.1	1.29
60	0.6	2.1	3.6	5.1	0.3	5.5	0.6	5.8	0.90

Meridional arcs.	
1″	30.9
2	61.7
3	92.6
4	123.5
5	154.3
6	185.2
7	216.1
8	247.0
9	277.8
10	308.7
20	617.4
30	926.1
40	1234.8
50	1543.5
1′ 00	1852.2
2	3704.3
3	5556.5
4	7408.6
5	9260.8
6	11113.0
7	12965.1
8	14817.3
9	16669.4
10	18521.5
11	20373.7
12	22225.8

Co-ordinates of curvature. Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.2
5	.0	3.4
6	.0	4.9
7	.0	6.6
8	.0	8.6
9	.0	10.9
10	.0	13.5
15	.0	30.4
20	.1	54.0
25	.1	84.4
30	.2	121.6
35	.3	165.5
40	.4	216.2
45	.6	273.6
50	.9	337.8
55	1.2	408.7
1° 00	1.5	486.4
1 10	2.4	662.1
1 20	3.6	864.7
1 30	5.1	1094.5
1 40	7.1	1351.1
1 50	9.3	1635.0
2 00	12.1	1945.7

TABLE VI.—*Projection Tables*—Cont'nued.

LATITUDE 46° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	150. 6	172. 1	193. 6	215. 1	430. 3	645. 5	860. 6	1075. 8	1290. 90
1	0. 5	2. 1	3. 6	5. 1	0. 2	5. 3	0. 3	5. 4	0. 51
2	0. 5	2. 0	3. 5	5. 0	0. 0	5. 1	0. 1	5. 1	0. 12
3	0. 5	2. 0	3. 5	5. 0	29. 9	4. 9	859. 8	4. 8	89. 73
4	0. 4	1. 9	3. 4	4. 9	9. 8	4. 7	9. 6	4. 5	9. 35
5	0. 4	1. 9	3. 3	4. 8	9. 7	4. 5	9. 3	4. 1	8. 96
6	150. 3	171. 8	193. 3	214. 8	429. 5	644. 3	859. 0	1073. 8	1288. 57
7	0. 3	1. 8	3. 2	4. 7	9. 4	4. 1	8. 8	3. 5	8. 18
8	0. 2	1. 7	3. 2	4. 6	9. 3	3. 9	8. 5	3. 2	7. 79
9	0. 2	1. 7	3. 1	4. 6	9. 1	3. 7	8. 3	2. 8	7. 41
10	0. 2	1. 6	3. 1	4. 5	9. 0	3. 5	8. 0	2. 5	7. 02
11	150. 1	171. 6	193. 0	214. 4	428. 9	643. 3	857. 8	1072. 2	1286. 63
12	0. 1	1. 5	2. 9	4. 4	8. 7	3. 1	7. 5	1. 9	6. 24
13	0. 0	1. 4	2. 9	4. 3	8. 6	2. 9	7. 2	1. 5	5. 85
14	0. 0	1. 4	2. 8	4. 2	8. 5	2. 7	7. 0	1. 2	5. 46
15	149. 9	1. 3	2. 8	4. 2	8. 4	2. 5	6. 7	0. 9	5. 07
16	149. 9	171. 3	192. 7	214. 1	428. 2	642. 3	856. 5	1070. 6	1284. 68
17	9. 8	1. 2	2. 6	4. 0	8. 1	2. 1	6. 2	0. 2	4. 29
18	9. 8	1. 2	2. 6	4. 0	8. 0	1. 9	5. 9	69. 9	3. 90
19	9. 7	1. 1	2. 5	3. 9	7. 8	1. 8	5. 7	9. 6	3. 51
20	9. 7	1. 1	2. 5	3. 9	7. 7	1. 6	5. 4	9. 3	3. 12
21	149. 7	171. 0	192. 4	213. 8	427. 6	641. 4	855. 2	1068. 9	1282. 73
22	9. 6	1. 0	2. 4	3. 7	7. 4	1. 2	4. 9	8. 6	2. 34
23	9. 6	0. 9	2. 3	3. 7	7. 3	1. 0	4. 6	8. 3	1. 95
24	9. 5	0. 9	2. 2	3. 6	7. 2	0. 8	4. 4	8. 0	1. 56
25	9. 5	0. 8	2. 2	3. 5	7. 1	0. 6	4. 1	7. 7	1. 17
26	149. 4	170. 8	192. 1	213. 5	426. 9	640. 4	853. 9	1067. 3	1280. 78
27	9. 4	0. 7	2. 1	3. 4	6. 8	0. 2	3. 6	7. 0	0. 39
28	9. 3	0. 7	2. 0	3. 3	6. 7	0. 0	3. 3	6. 7	0. 00
29	9. 3	0. 6	1. 9	3. 3	6. 5	39. 8	3. 1	6. 3	79. 61
30	9. 2	0. 6	1. 9	3. 2	6. 4	9. 6	2. 8	6. 0	1279. 22

Meridional arcs.	
1″	30. 9
2	61. 7
3	92. 6
4	123. 5
5	154. 4
6	185. 2
7	216. 1
8	247. 0
9	277. 8
10	308. 7
20	617. 4
30	926. 2
40	1234. 9
50	1543. 6
1′ 00	1852. 3
2	3704. 6
3	5556. 9
4	7409. 3
5	9261. 6
6	11113. 9
7	12966. 2
8	14818. 5
9	16670. 8
10	18523. 1
11	20375. 5
12	22227. 8

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—. 0	. 1
2	. 0	. 5
3	. 0	1. 2
4	. 0	2. 2
5	. 0	3. 4
6	. 0	4. 9
7	. 0	6. 6
8	. 0	8. 6
9	. 0	10. 9
10	. 0	13. 5
15	. 0	30. 4
20	. 1	54. 0
25	. 1	84. 4
30	. 2	121. 6
35	. 3	165. 4
40	. 5	216. 1
45	. 6	273. 5
50	. 9	337. 6
55	1. 2	408. 5
1° 00	1. 5	486. 2
1 10	2. 4	661. 8
1 20	3. 6	864. 4
1 30	5. 2	1094. 0
1 40	7. 1	1350. 6
1 50	9. 4	1634. 2
2 00	12. 2	1944. 9

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 46° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	149.2	170.6	191.9	213.2	426.4	639.6	852.8	1066.0	1279.22
31	9.2	0.5	1.8	3.1	6.3	9.4	2.6	5.7	8.83
32	9.2	0.5	1.8	3.1	6.1	9.2	2.3	5.4	8.84
33	9.1	0.4	1.7	3.0	6.0	9.0	2.0	5.0	8.05
34	9.1	0.4	1.6	2.9	5.9	8.8	1.8	4.7	7.66
35	9.0	0.3	1.6	2.9	5.8	8.6	1.5	4.4	7.27
36	149.0	170.2	191.5	212.8	425.6	638.4	851.2	1064.1	1276.87
37	8.9	0.2	1.5	2.7	5.5	8.2	1.0	3.7	6.48
38	8.9	0.1	1.4	2.7	5.4	8.0	0.7	3.4	6.09
39	8.8	0.1	1.4	2.6	5.2	7.8	0.5	3.1	5.70
40	8.8	0.0	1.3	2.6	5.1	7.7	0.2	2.8	5.31
41	148.7	170.0	191.2	212.5	425.0	637.5	850.0	1062.4	1274.91
42	8.7	69.9	1.2	2.4	4.8	7.3	49.7	2.1	4.52
43	8.6	9.9	1.1	2.4	4.7	7.1	9.4	1.8	4.13
44	8.6	9.8	1.1	2.3	4.6	6.9	9.2	1.5	3.74
45	8.6	9.8	1.0	2.2	4.4	6.7	8.9	1.1	3.35
46	148.5	169.7	190.9	212.2	424.3	636.5	848.6	1060.8	1272.95
47	8.5	9.7	0.9	2.1	4.2	6.3	8.4	0.5	2.56
48	8.4	9.6	0.8	2.0	4.1	6.1	8.1	0.1	2.17
49	8.4	9.6	0.8	2.0	3.9	5.9	7.9	1059.8	1.77
50	8.3	9.5	0.7	1.9	3.8	5.7	7.6	9.5	1.38
51	148.3	169.5	190.6	211.8	423.7	635.5	847.3	1059.2	1270.99
52	8.2	9.4	0.6	1.8	3.5	5.3	7.1	8.8	0.60
53	8.2	9.4	0.5	1.7	3.4	5.1	6.8	8.5	0.20
54	8.1	9.3	0.5	1.6	3.3	4.9	6.5	8.2	69.81
55	8.1	9.3	0.4	1.6	3.1	4.7	6.3	7.9	9.42
56	148.1	169.2	190.4	211.5	423.0	634.5	846.0	1057.5	1269.02
57	8.0	9.2	0.3	1.4	2.9	4.3	5.7	7.2	8.63
58	8.0	9.1	0.2	1.4	2.8	4.1	5.5	6.9	8.23
59	7.9	9.1	0.2	1.3	2.6	3.9	5.2	6.5	7.84
60	7.9	9.0	0.1	1.2	2.5	3.7	5.0	6.2	7.45

Meridional arcs.	
1″	30.9
2	61.7
3	92.6
4	123.5
5	154.4
6	185.2
7	216.1
8	247.0
9	277.9
10	308.7
20	617.5
30	926.2
40	1235.0
50	1543.7
1′ 00	1852.5
2	3705.0
3	5557.4
4	7409.9
5	9262.4
6	11114.9
7	12967.4
8	14819.8
9	16672.3
10	18524.8
11	20377.3
12	22229.7

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.2
5	.0	3.4
6	.0	4.9
7	.0	6.6
8	.0	8.6
9	.0	10.9
10	.0	13.5
15	.0	30.4
20	.1	54.0
25	.1	84.3
30	.2	121.5
35	.3	165.3
40	.5	215.9
45	.6	273.3
50	.9	337.4
55	1.2	408.3
1° 00	1.5	485.9
1 10	2.4	661.3
1 20	3.6	863.7
1 30	5.2	1093.2
1 40	7.1	1349.6
1 50	9.5	1633.1
2 00	12.3	1943.4

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 47° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.) 7″	8″	9″	10″	20″	30″	40″	50″	60″
0′	147.9	169.0	190.1	211.2	422.5	633.7	845.0	1056.2	1267.45
1	7.8	9.0	0.0	1.2	2.3	3.5	4.7	5.9	7.05
2	7.8	8.9	0.0	1.1	2.2	3.3	4.4	5.5	6.66
3	7.7	8.8	189.9	1.0	2.1	3.1	4.2	5.2	6.26
4	7.7	8.8	9.9	1.0	2.0	2.9	3.9	4.9	5.87
5	7.6	8.7	9.8	0.9	1.8	2.7	3.7	4.6	5.47
6	147.6	168.7	189.8	210.8	421.7	632.5	843.4	1054.2	1265.08
7	7.5	8.6	9.7	0.8	1.6	2.3	3.1	3.9	4.68
8	7.5	8.6	9.6	0.7	1.4	2.1	2.9	3.6	4.29
9	7.5	8.5	9.6	0.6	1.3	1.9	2.6	3.2	3.89
10	7.4	8.5	9.5	0.6	1.2	1.7	2.3	2.9	3.50
11	147.4	168.4	189.5	210.5	421.0	631.5	842.1	1052.6	1263.10
12	7.3	8.4	9.4	0.4	0.9	1.4	1.8	2.3	2.71
13	7.3	8.3	9.3	0.4	0.8	1.2	1.5	1.9	2.31
14	7.2	8.3	9.3	0.3	0.6	1.0	1.3	1.6	1.92
15	7.2	8.2	9.2	0.3	0.5	0.8	1.0	1.3	1.52
16	147.1	168.2	189.2	210.2	420.4	630.6	840.8	1050.9	1261.13
17	7.1	8.1	9.1	0.1	0.2	0.4	0.5	0.6	0.73
18	7.0	8.0	9.0	0.1	0.1	0.2	0.2	0.3	0.33
19	7.0	8.0	9.0	0.0	0.0	0.0	0.0	49 9	59.94
20	6.9	7.9	8.9	209.9	419.9	29.8	39.7	9.6	9.54
21	146.9	167.9	188.9	209.9	419.7	629.6	839.4	1049.3	1259.15
22	6.9	7.8	8.8	9.8	9.6	9.4	9.2	9.0	8.75
23	6.8	7.8	8.8	9.7	9.4	9.2	8.9	8.7	8.35
24	6.8	7.7	8.7	9.7	9.3	9.0	8.6	8.3	7.96
25	6.7	7.7	8.6	9.6	9.2	8.8	8.4	8.0	7.56
26	146.7	167.6	188.6	209.5	419.1	628.6	838.1	1047.6	1257.16
27	6.6	7.6	8.5	9.5	8.9	8.4	7.8	7.3	6.77
28	6.6	7.5	8.5	9.4	8.8	8.2	7.6	7.0	6.37
29	6.5	7.5	8.4	9.3	8.7	8.0	7.3	6.7	5.97
30	6.5	7.4	8.3	9.3	8.5	7.8	7.0	6.3	5.57

Meridional arcs.	
1″	30.9
2	61.8
3	92.6
4	123.5
5	154.4
6	185.3
7	216.1
8	247.0
9	277.9
10	308.8
20	617.5
30	926.3
40	1235.1
50	1543.9
1′ 00	1852.6
2	3705.3
3	5557.9
4	7410.6
5	9263.2
6	11115.9
7	12968.5
8	14821.1
9	16673.8
10	18526.4
11	20379.0
12	22231.7

Co-ordinates of curvature. Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.2
5	.0	3.4
6	.0	4.9
7	.0	6.6
8	.0	8.6
9	.0	10.9
10	.0	13.5
15	.0	30.3
20	.1	53.9
25	.1	84.3
30	.2	121.3
35	.3	165.2
40	.5	215.7
45	.7	273.0
50	.9	337.0
55	1.2	407.8
1° 00	1.5	485.3
1 10	2.5	660.6
1 20	3.7	862.8
1 30	5.2	1092.0
1 40	7.2	1348.2
1 50	9.5	1631.4
2 00	12.4	1941.4

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 47° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10	20″	30″	40″	50″	60″
30′	146.5	167.4	188.3	209.3	418.5	627.8	837.0	1046.3	1255.57
31	6.4	7.4	8.3	9.2	8.4	7.6	6.8	6.0	5.18
32	6.4	7.3	8.2	9.1	8.3	7.4	6.5	5.6	4.78
33	6.3	7.3	8.2	9.1	8.1	7.2	6.3	5.3	4.38
34	6.3	7.2	8.1	9.0	8.0	7.0	6.0	5.0	3.98
35	6.3	7.1	8.0	8.9	7.9	6.8	5.7	4.7	3.59
36	146.2	167.1	188.0	208.9	417.7	626.6	835.5	1044.3	1253.19
37	6.2	7.0	7.9	8.8	7.6	6.4	5.2	4.0	2.79
38	6.1	7.0	7.9	8.7	7.5	6.2	4.9	3.7	2.39
39	6.1	6.9	7.8	8.7	7.3	6.0	4.7	3.4	1.99
40	6.0	6.9	7.7	8.6	7.2	5.8	4.4	3.0	1.59
41	146.0	166.8	187.7	208.5	417.1	625.6	834.1	1042.7	1251.20
42	5.9	6.8	7.6	8.5	6.9	5.4	3.9	2.3	0.80
43	5.9	6.7	7.6	8.4	6.8	5.2	3.6	2.0	0.40
44	5.8	6.7	7.5	8.3	6.7	5.0	3.3	1.7	0.00
45	5.8	6.6	7.4	8.3	6.5	4.8	3.1	1.3	49.60
46	145.7	166.6	187.4	208.2	416.4	624.6	832.8	1041.0	1249.20
47	5.7	6.5	7.3	8.1	6.3	4.4	2.5	0.7	8.80
48	5.6	6.5	7.3	8.1	6.1	4.2	2.3	0.3	8.40
49	5.6	6.4	7.2	8.0	6.0	4.0	2.0	0.0	8.00
50	5.6	6.3	7.1	7.9	5.9	3.8	1.7	39.7	7.60
51	145.5	166.3	187.1	207.9	415.7	623.6	831.5	1039.4	1247.21
52	5.5	6.2	7.0	7.8	5.6	3.4	1.2	9.0	6.81
53	5.4	6.2	7.0	7.7	5.5	3.2	0.9	8.7	6.41
54	5.4	6.1	6.9	7.7	5.3	3.0	0.7	8.3	6.01
55	5.3	6.1	6.8	7.6	5.2	2.8	0.4	8.0	5.61
56	145.3	166.0	186.8	207.5	415.1	622.6	830.1	1037.7	1245.21
57	5.2	6.0	6.7	7.5	4.9	2.4	29.9	7.4	4.81
58	5.2	5.9	6.7	7.4	4.8	2.2	9.6	7.0	4.41
59	5.1	5.9	6.6	7.3	4.7	2.0	9.3	6.7	4.01
60	5.1	5.8	6.5	7.3	4.5	1.8	9.1	6.3	3.60

Meridional arcs.	
1″	30.9
2	61.8
3	92.6
4	123.5
5	154.4
6	185.3
7	216.2
8	247.0
9	277.9
10	308.8
20	617.6
30	926.4
40	1235.2
50	1544.0
1′ 00	1852.8
2	3705.6
3	5558.4
4	7411.2
5	9264.0
6	11116.8
7	12969.6
8	14822.4
9	16675.2
10	18528.0
11	20380.8
12	22233.6

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.2
5	.0	3.4
6	.0	4.8
7	.0	6.6
8	.0	8.6
9	.0	10.9
10	.0	13.5
15	.0	30.3
20	.1	53.9
25	.1	84.2
30	.2	121.2
35	.3	164.9
40	.5	215.4
45	.7	272.6
50	.9	336.6
55	1.2	407.3
1° 00	1.6	484.7
1 10	2.5	659.7
1 20	3.7	861.7
1 30	5.3	1090.5
1 40	7.2	1346.4
1 50	9.6	1629.2
2 00	12.5	1938.7

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 48° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)									Meridional arcs.		Co-ordinates of curvature.		
	7″	8″	9″	10″	20″	30″	40″	50″	60″			Minutes of longitude.	X. Arc. par.	Y.
0′	145.1	165.8	186.5	207.3	414.5	621.8	829.1	1036.3	1243.60	1″	30.9	1′	—.0	.1
1	5.0	5.8	6.5	7.2	4.4	1.6	8.8	6.0	3.20	2	61.8	2	.0	.5
2	5.0	5.7	6.4	7.1	4.3	1.4	8.5	5.7	2.80	3	92.6	3	.0	1.2
3	4.9	5.7	6.4	7.1	4.1	1.2	8.3	5.3	2.40	4	123.5	4	.0	2.2
4	4.9	5.6	6.3	7.0	4.0	1.0	8.0	5.0	2.00					
5	4.9	5.5	6.2	6.9	3.9	0.8	7.7	4.7	1.60	5	154.4	5	.0	3.4
										6	185.3	6	.0	4.8
6	144.8	165.5	186.2	206.9	413.7	620.6	827.5	1034.3	1241.20	7	216.2	7	.0	6.6
7	4.8	5.4	6.1	6.8	3.6	0.4	7.2	4.0	0.80	8	247.1	8	.0	8.6
8	4.7	5.4	6.1	6.7	3.5	0.2	6.9	3.7	0.40	9	277.9	9	.0	10.9
9	4.7	5.3	6.0	6.7	3.3	0.0	6.7	3.3	0.00					
10	4.6	5.3	5.9	6.6	3.2	19.8	6.4	3.0	39.59	10	308.8	10	.0	13.4
										20	617.7	15	.0	30.2
11	144.6	165.2	185.9	206.5	413.1	619.6	826.1	1032.7	1239.19	30	926.5	20	.1	53.8
12	4.5	5.2	5.8	6.5	2.9	9.4	5.9	2.3	8.79	40	1235.3	25	.1	84.0
13	4.5	5.1	5.8	6.4	2.8	9.2	5.6	2.0	8.39	50	1544.1	30	.2	121.0
14	4.4	5.1	5.7	6.3	2.7	9.0	5.3	1.7	7.99					
15	4.4	5.0	5.6	6.3	2.5	8.8	5.1	1.3	7.59	1′ 00	1853.0	35	.3	164.7
										2	3705.9	40	.5	215.1
16	144.3	165.0	185.6	206.2	412.4	618.6	824.8	1031.0	1237.18	3	5558.9	45	.7	272.2
17	4.3	4.9	5.5	6.1	2.3	8.4	4.6	0.6	6.78	4	7411.9	50	.9	336.0
18	4.2	4.9	5.5	6.1	2.1	8.2	4.3	0.3	6.38	5	9264.8	55	1.2	406.6
19	4.2	4.8	5.4	6.0	2.0	8.0	4.0	0.0	5.97	6	11117.8			
20	4.2	4.7	5.3	5.9	1.9	7.8	3.7	29.6	5.57			1° 00	1.6	483.9
										7	12970.7	1 10	2.5	658.6
21	144.1	164.7	185.3	205.9	411.7	617.6	823.4	1029.3	1235.17	8	14823.7	1 20	3.7	860.3
22	4.1	4.6	5.2	5.8	1.6	7.4	3.2	9.0	4.77	9	16676.7	1 30	5.3	1088.7
23	4.0	4.6	5.2	5.7	1.5	7.2	2.9	8.6	4.36	10	18529.6	1 40	7.3	1344.2
24	4.0	4.5	5.1	5.7	1.3	7.0	2.6	8.3	3.96	11	20382.6	1 50	9.7	1626.4
25	3.9	4.5	5.0	5.6	1.2	6.8	2.4	8.0	3.56	12	22235.6	2 00	12.6	1935.5
26	143.9	164.4	185.0	205.5	411.0	616.6	822.1	1027.6	1233.15					
27	3.8	4.4	4.9	5.5	0.9	6.4	1.8	7.3	2.75					
28	3.8	4.3	4.9	5.4	0.8	6.2	1.6	7.0	2.35					
29	3.7	4.3	4.8	5.3	0.6	6.0	1.3	6.6	1.94					
30	3.7	4.2	4.7	5.3	0.5	5.8	1.0	6.3	1.54					

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 48° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	143.7	164.2	184.7	205.3	410.5	615.8	821.0	1026.3	1231.54
31	3.6	4.2	4.7	5.2	0.4	5.6	0.8	5.9	1.14
32	3.6	4.1	4.6	5.1	0.2	5.4	0.5	5.6	0.73
33	3.5	4.0	4.5	5.1	0.1	5.2	0.2	5.2	0.33
34	3.5	4.0	4.5	5.0	0.0	5.0	0.0	4.9	29.93
35	3.4	3.9	4.4	4.9	409.8	4.8	819.7	4.6	9.52
36	143.4	163.9	184.4	204.9	409.7	614.6	819.4	1024.3	1229.12
37	3.4	3.8	4.3	4.8	9.6	4.4	9.1	3.9	8.71
38	3.3	3.8	4.2	4.7	9.4	4.2	8.9	3.6	8.31
39	3.3	3.7	4.2	4.6	9.3	4.0	8.6	3.3	7.90
40	3.2	3.7	4.1	4.6	9.2	3.7	8.3	2.9	7.50
41	143.2	163.6	184.1	204.5	409.0	613.5	818.1	1022.6	1227.09
42	3.1	3.6	4.0	4.4	8.9	3.3	7.8	2.2	6.69
43	3.1	3.5	3.9	4.4	8.8	3.1	7.5	1.9	6.28
44	3.0	3.5	3.9	4.3	8.6	2.9	7.3	1.6	5.88
45	3.0	3.4	3.8	4.2	8.5	2.7	7.0	1.2	5.47
46	142.9	163.3	183.8	204.2	408.4	612.5	816.7	1020.9	1225.07
47	2.9	3.3	3.7	4.1	8.2	2.3	6.4	0.6	4.66
48	2.8	3.2	3.6	4.0	8.1	2.1	6.2	0.2	4.26
49	2.8	3.2	3.6	4.0	8.0	1.9	5.9	19.9	3.85
50	2.7	3.1	3.5	3.9	7.8	1.7	5.6	9.5	3.45
51	142.7	163.1	183.5	203.8	407.7	611.5	815.4	1019.2	1223.04
52	2.6	3.0	3.4	3.8	7.5	1.3	5.1	8.9	2.63
53	2.6	3.0	3.3	3.7	7.4	1.1	4.8	8.5	2.23
54	2.5	2.9	3.3	3.6	7.3	0.9	4.5	8.2	1.82
55	2.5	2.9	3.2	3.6	7.1	0.7	4.3	7.8	1.42
56	142.5	162.8	183.2	203.5	407.0	610.5	814.0	1017.5	1221.01
57	2.4	2.7	3.1	3.4	6.9	0.3	3.7	7.2	20.60
58	2.4	2.7	3.0	3.4	6.7	0.1	3.5	6.8	20.19
59	2.3	2.6	3.0	3.3	6.6	609.9	3.2	6.5	19.79
60	2.3	2.6	2.9	3.2	6.5	9.7	2.9	6.1	19.38

Meridional arcs.	
1″	30.9
2	61.8
3	92.7
4	123.5
5	154.4
6	185.3
7	216.2
8	247.1
9	278.0
10	308.9
20	617.7
30	926.6
40	1235.4
50	1544.3
1′ 00	1853.1
2	3706.2
3	5559.4
4	7412.5
5	9265.6
6	11118.7
7	12971.9
8	14825.0
9	16678.1
10	18531.2
11	20384.4
12	22237.5

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.1
5	.0	3.4
6	.0	4.8
7	.0	6.6
8	.0	8.6
9	.0	10.9
10	.0	13.4
15	.0	30.2
20	.1	53.7
25	.1	83.8
30	.2	120.7
35	.3	164.3
40	.5	214.6
45	.7	271.7
50	.9	335.4
55	1.2	405.8
1° 00	1.6	483.0
1 10	2.5	657.4
1 20	3.8	858.6
1 30	5.3	1086.6
1 40	7.3	1341.5
1 50	9.8	1623.2
2 00	12.6	1931.8

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 49° 00′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7′′	8′′	9′′	10′′	20′′	30′′	40′′	50′′	60′′
0′	142.3	162.6	182.9	203.2	406.5	609.7	812.9	1016.1	1219.38
1	2.2	2.5	2.8	3.2	6.3	9.5	2.6	5.8	8.97
2	2.2	2.5	2.8	3.1	6.2	9.3	2.4	5.5	8.57
3	2.1	2.4	2.7	3.0	6.1	9.1	2.1	5.1	8.16
4	2.1	2.4	2.7	3.0	5.9	8.9	1.8	4.8	7.75
5	2.0	2.3	2.6	2.9	5.8	8.7	1.6	4.5	7.35
6	142.0	162.3	182.5	202.8	405.6	608.5	811.3	1014.1	1216.94
7	1.9	2.2	2.5	2.8	5.5	8.3	1.0	3.8	6.53
8	1.9	2.1	2.4	2.7	5.4	8.1	0.7	3.4	6.12
9	1.8	2.1	2.4	2.6	5.2	7.9	0.5	3.1	5.72
10	1.8	2.0	2.3	2.6	5.1	7.7	0.2	2.8	5.31
11	141.7	162.0	182.2	202.5	405.0	607.5	809.9	1012.4	1214.90
12	1.7	1.9	2.2	2.4	4.8	7.2	9.7	2.1	4.49
13	1.6	1.9	2.1	2.3	4.7	7.0	9.4	1.7	4.08
14	1.6	1.8	2.1	2.3	4.6	6.8	9.1	1.4	3.68
15	1.5	1.8	2.0	2.2	4.4	6.6	8.8	1.1	3.27
16	141.5	161.7	181.9	202.1	404.3	606.4	808.6	1010.7	1212.86
17	1.5	1.7	1.9	2.1	4.1	6.2	8.3	0.4	2.45
18	1.4	1.6	1.8	2.0	4.0	6.0	8.0	0.0	2.04
19	1.4	1.6	1.7	1.9	3.9	5.8	7.8	1009.7	1.63
20	1.3	1.5	1.7	1.9	3.7	5.6	7.5	9.4	1.22
21	141.3	161.4	181.6	201.8	403.6	605.4	807.2	1009.0	1210.81
22	1.2	1.4	1.6	1.7	3.5	5.2	6.9	8.7	0.40
23	1.2	1.3	1.5	1.7	3.3	5.0	6.7	8.3	0.00
24	1.1	1.3	1.4	1.6	3.2	4.8	6.4	8.0	1209.59
25	1.1	1.2	1.4	1.5	3.1	4.6	6.1	7.7	9.18
26	141.0	161.2	181.3	201.5	402.9	604.4	805.8	1007.3	1208.77
27	1.0	1.1	1.3	1.4	2.8	4.2	5.6	7.0	8.36
28	0.9	1.1	1.2	1.3	2.7	4.0	5.3	6.6	7.95
28	0.9	1.0	1.1	1.3	2.5	3.8	5.0	6.3	7.54
30	0.8	1.0	1.1	1.2	2.4	3.6	4.8	5.9	7.13

Meridional arcs.	
1′′	30.9
2	61.8
3	92.7
4	123.6
5	154.4
6	185.3
7	216.2
8	247.1
9	278.0
10	308.9
20	617.8
30	926.6
40	1235.5
50	1544.4
1′ 00	1853.3
2	3706.6
3	5559.9
4	7413.1
5	9266.4
6	11119.7
7	12973.0
8	14826.3
9	16679.6
10	18532.9
11	20386.1
12	22239.4

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.1
5	.0	3.3
6	.0	4.8
7	.0	6.6
8	.0	8.6
9	.0	10.8
10	.0	13.4
15	.0	30.1
20	.1	53.5
25	.1	83.7
30	.2	120.5
35	.3	164.0
40	.5	214.2
45	.7	271.0
50	.9	334.6
55	1.2	404.9
1° 00	1.6	481.9
1 10	2.5	655.9
1 20	3.8	856.6
1 30	5.3	1084.1
1 40	7.3	1338.5
1 50	9.8	1619.6
2 00	12.7	1927.4

TABLE VI.—*Projection Tables*—Continued.

LATITUDE 49° 30′.

Min.	Length in metres of arcs of the parallel, (arc par.)								
	7″	8″	9″	10″	20″	30″	40″	50″	60″
30′	140.8	161.0	181.1	201.2	402.4	603.6	804.8	1005.9	1207.13
31	0.8	0.9	1.0	1.1	2.2	3.4	4.5	5.6	6.72
32	0.7	0.8	0.9	1.1	2.1	3.2	4.2	5.3	6.31
33	0.7	0.8	0.9	1.0	2.0	2.9	3.9	4.9	5.90
34	0.6	0.7	0.8	0.9	1.8	2.7	3.7	4.6	5.49
35	0.6	0.7	0.8	0.8	1.7	2.5	3.4	4.2	5.08
36	140.5	160.6	180.7	200.8	401.6	602.3	803.1	1003.9	1204.67
37	0.5	0.6	0.6	0.7	1.4	2.1	2.9	3.6	4.26
38	0.4	0.5	0.6	0.6	1.3	1.9	2.6	3.2	3.85
39	0.4	0.5	0.5	0.6	1.1	1.7	2.3	2.9	3.44
40	0.4	0.4	0.5	0.5	1.0	1.5	2.0	2.5	3.02
41	140.3	160.3	180.4	200.4	400.9	601.3	801.7	1002.2	1202.61
42	0.3	0.3	0.3	0.4	0.7	1.1	1.5	1.8	2.20
43	0.2	0.2	0.3	0.3	0.6	0.9	1.2	1.5	1.79
44	0.2	0.2	0.2	0.2	0.5	0.7	0.9	1.1	1.38
45	0.1	0.1	0.1	0.2	0.3	0.5	0.6	0.8	0.97
46	140.1	160.1	180.1	200.1	400.2	600.3	800.4	1000.4	1200.56
47	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.14
48	0.0	0.0	0.0	0.0	399.9	599.9	799.8	999.8	1199.73
49	139.9	159.9	179.9	199.9	9.8	9.7	9.5	9.4	9.32
50	9.9	9.9	9.8	9.8	9.6	9.5	9.3	9.1	8.91
51	139.8	159.8	179.8	199.8	399.5	599.2	799.0	998.8	1198.50
52	9.8	9.7	9.7	9.7	9.4	9.0	8.8	8.4	8.08
53	9.7	9.7	9.7	9.6	9.2	8.8	8.4	8.1	7.67
54	9.7	9.6	9.6	9.5	9.1	8.6	8.2	7.7	7.26
55	9.6	9.6	9.5	9.5	8.9	8.4	7.9	7.4	6.85
56	139.6	159.5	179.5	199.4	398.8	598.2	797.6	997.0	1196.44
57	9.5	9.5	9.4	9.3	8.7	8.0	7.3	6.7	6.02
58	9.5	9.4	9.3	9.3	8.5	7.8	7.1	6.3	5.61
59	9.4	9.4	9.3	9.2	8.4	7.6	6.8	6.0	5.20
60	9.4	9.3	9.2	9.1	8.3	7.4	6.5	5.6	4.78

Meridional arcs.	
1″	30.9
2	61.8
3	92.7
4	123.6
5	154.5
6	185.3
7	216.2
8	247.1
9	278.0
10	308.9
20	617.8
30	926.7
40	1235.6
50	1544.5
1′ 00	1853.4
2	3706.9
3	5560.3
4	7413.8
5	9267.2
6	11120.7
7	12974.1
8	14827.6
9	16681.0
10	18534.5
11	20387.9
12	22241.4

Co-ordinates of curvature.		
Minutes of longitude.	X. Arc par.	Y.
1′	—.0	.1
2	.0	.5
3	.0	1.2
4	.0	2.1
5	.0	3.3
6	.0	4.8
7	.0	6.5
8	.0	8.5
9	.0	10.8
10	.0	13.4
15	.0	30.0
20	.1	53.4
25	.1	83.4
30	.2	120.2
35	.3	163.6
40	.5	213.6
45	.7	270.3
50	.9	333.7
55	1.2	403.8
1° 00	1.6	480.6
1 10	2.5	654.2
1 20	3.8	854.4
1 30	5.4	1081.3
1 40	7.4	1335.0
1 50	9.8	1615.4
2 00	12.8	1922.4

Table for projecting maps of large extent, arranged by Assistant J. E. Hilgard.

The tables are based on a polyconic development of the earth's surface, which supposes each parallel of latitude represented on a plane by the development of a cone having the parallel for its base, and its vertex in the point where a tangent to the parallel intersects the earth's axis. The degrees on the parallel preserve their true length, and the general distortion of area is less than in any other mode of representing a given portion of the earth's surface.

Denoting by a the equatorial radius of the spheroid, e the eccentricity, then the normal to any point on the parallel of latitude L, is $\mathrm{N} = \frac{a}{(1 - e^2 \sin^2 \mathrm{L})^{\frac{1}{2}}}$. The radius of the parallel $\mathrm{R}p = \mathrm{N} \cos \mathrm{L}$; and the radius of the developed parallel, or the side of the tangent cone $r = \mathrm{N} \cot \mathrm{L}$. Designating by n any arc of the parallel, or difference of longitude to be developed, and by θ the corresponding angle subtended by the developed parallel at the vertex of the cone, then the length of the given arc will be

$$n \mathrm{R}p = n \mathrm{N} \cos \mathrm{L},$$

and also $\theta r \;= \theta \mathrm{N} \cot \mathrm{L}$; and hence $\theta = n \sin \mathrm{L}$.

To determine rectangular co-ordinates X and Y, for projecting from the middle meridian the points of intersection of the meridians and parallels, we have simply, the developed parallels being arcs of circles,

$$\mathrm{X} = r \sin \theta, \qquad \mathrm{Y} = r \operatorname{versin} \theta.$$

Table I gives the co-ordinates for thirty degrees of longitude on each parallel, from latitude 20° to 54°. The numbers correspond to the actual dimensions of the earth in metres, and are to be divided by the proper number for any desired scale.

Table II gives the length, in metres, of one degree of latitude and longitude, for each degree of latitude, from 20° to 54°; also the radii of the developed parallels, which may be used to describe the parallels by means of beam-compasses, when the scale permits. It also gives the values of θ for 10° of longitude, by means of which the tables may readily be extended.

In order to project a map by the aid of these tables, draw a straight line as middle meridian of the map, on which space off the required degrees of latitude by the values given in Table II. Through the points so marked construct lines perpendicular to the meridian, and parallel with each other, which will be tangents to the parallels of latitude at their intersection with the middle meridian.

On these tangents lay off, from the middle meridian, for each required longitude the corresponding X from the tables, and offset Y perpendicular to it, to the northward. Through the points so found, draw continuous curves for the parallels and meridians.

Tables III, IV, and V are auxiliaries for converting metres into yards and miles, and reciprocally, to accommodate the values in the preceding tables to other units. It will, however, be obvious to every experienced draughtsman, that, in place of making a great many numerical conversions, it will be preferable, in every case in which the scale used is not a simple fraction of the natural size—such as one-millionth part or one ten-millionth part of nature—to draw a scale so divided and numbered that the values from the tables can be immediately taken off. For instance, if it is required to project a map on a scale of 50 miles to 1 inch, we find in Table III. B., that 50 miles are equal to 80,470 metres; we construct a scale, therefore, on which 1 inch is called 80,470 metres, or we make 1.2427*in.* = 100,000 metres, and with this scale work from the Tables of X and Y, with unchanged numbers.

When the polyconic development is extended to the whole surface of the sphere, a figure results, which is represented on Sketch No. 65. The distortion, unavoidable in any representation of a spherical surface on a plane, is here greatest in the equatorial regions near the eastern and

western extremities of the map. The circumpolar regions are well represented, and it is believed that this projection will be found preferable to Mercator's for maps illustrating various points of physical geography, the only kind for which representations of the whole sphere are likely to be desirable.

Table VI gives the data for the projection of a sphere on this principle. Draw the central meridian from pole to pole = 3.142, the radius of the sphere being assumed = 1. On this meridian space off every tenth degree of latitude, and, through the points so obtained, describe the parallels with the corresponding radii from the table, and construct their limits by the co-ordinates x and y. On each parallel, space off equidistant meridians with the values of 10° of parallel given in the table, and, through the points so determined, draw (with a curve board or piece of whalebone) continuous curves for the meridians. In the projection of a hemisphere the limiting line differs but little from a circle, as will be perceived by tracing out the meridian 90° East and West on the map. While this mode of representing a hemisphere is undoubtedly the best that can be devised for preservation of areas and azimuths, the following modification approaches to it so nearly, and is so simple in its construction, that it deserves particular notice.

The radius of the sphere being assumed = 1, with a radius of 1.571 describe a circle as limiting line, and draw diameters for equator and central meridian; describe each parallel with a radius equal to the cotangent of the latitude, as given in Table VI, and divide them into equal parts for the intersections of meridians.

This is, in fact, a method in common use, and although empirical in its nature, that is to say, not representing any geometrical idea of projection or development, it varies from the very best method by quantities quite inconsiderable where the representation necessarily deviates very far from nature.

The following constants may be found useful:

Equatorial radius of earth $a =$ 6377397 metres: log. = 6.80464346
Polar radius of earth $b =$ 6356079 " " = 6.80318928
Square of the eccentricity $\frac{a^2 - b^2}{a^2} = e^2 = 0.00667437$ " = 7.8244104

1 metre = 39.36850 inches of the United States standard scale.

TABLE I.

Table of co-ordinates for projecting the points of intersection of meridians and parallels.

Longitude.	Latitude 20°.		Latitude 21°.		Latitude 22°.		Latitude 23°.		Latitude 24°.		Latitude 25°.		Longitude.
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	
°	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	°
1	104,634	312	103,958	325	103.249	337	102,510	348	101,737	361	100,938	372	1
2	209,265	1,249	207,911	1,300	206,494	1,350	205,014	1,398	203,472	1,444	201,866	1,489	2
3	313,888	2,810	311,856	2,926	309,730	3,038	307,510	3,146	305,196	3,250	302,790	3,350	3
4	418,499	4,997	415,790	5,201	412,953	5,400	409,991	5,592	406,905	5,777	403,694	5,956	4
5	523,096	7,807	519,706	8,127	516,158	8,437	512,453	8,737	508,592	9,027	504,577	9,305	5
6	627,674	11,242	623,603	11,703	619,341	12,149	614,893	12,581	610,254	12,999	605,432	13,399	6
7	732,231	15,300	727,475	15,928	722,498	16,536	717,301	17,124	711,885	17,691	706,253	18,237	7
8	836,758	19,984	831,319	20,803	825,623	21,597	819,677	22,365	813,481	23,106	807,037	23,818	8
9	941,260	25,291	935,130	26,327	928,714	27,332	922,016	28,304	915.036	29,241	907,777	30,142	9
10	1,045,727	31,221	1,038,905	32,501	1,031,765	33,740	1,024,310	34,938	1,016,543	36,097	1,008,467	37,209	10
11	1,150,156	37,775	1,142,639	39,323	1,134,771	40,823	1,126,558	42,274	1,118,003	43,673	1,109,102	45,019	11
12	1.254.544	44,952	1,246,327	46,794	1,237,729	48,579	1,228,753	50,305	1,219.404	51,970	1,209,677	53,571	12
13	1,358,888	52,753	1,349,968	54,915	1,340,634	57,008	1,330,892	59,033	1,320,740	60,986	1,310,187	62,864	13
14	1,463,182	61,176	1,453,556	63,682	1,443,482	66,110	1,432,968	68,457	1,422,013	70,721	1,410,624	72,899	14
15	1,567,426	70,221	1,557,087	73,097	1,546,268	75,883	1,534,977	78,577	1,523,217	81,175	1,510,986	83,673	15
16	1,671,613	79,888	1,660,556	83,160	1,648,989	86,329	1,636,915	89,393	1,624,339	92,347	1,611,266	95,189	16
17	1,775,740	90,178	1,763,962	93,869	1,751,638	97,446	1,738,777	100,903	1,725,381	104,237	1.711,456	107,443	17
18	1,879,804	101,089	1,867,297	105,226	1,854,214	109,233	1,840,559	113,108	1,826,337	116,844	1,811,555	120,436	18
19	1,983,802	112,620	1,970,560	117,228	1,956,708	121,695	1,942,254	126,006	1,927,200	130,166	1,911,554	134,168	19
20	2,087,729	124,772	2,073,746	129,876	2,059,120	134,820	2,043,860	139,598	2,027,967	144,205	2,011,450	148,636	20
21	2,191,580	137,545	2,176,855	143,169	2,161,446	148,617	2,145,370	153,882	2,128,631	158,959	2,111,235	163,840	21
22	2,295,355	150,937	2,279,871	157,107	2,263,676	163,083	2,246,779	168,859	2,229,188	174,431	2,210,908	179,781	22
23	2,399,047	164,949	2,382,802	171,689	2,365,815	178,216	2,348,086	184,526	2,329,632	190,608	2,310,458	196,456	23
24	2,502,654	179,578	2,485,639	186,914	2,467,844	194,019	2,449,282	200,885	2,429,959	207,503	2,409,884	213.865	24
25	2,606,172	194,827	2,588,378	202,782	2,569,772	210.487	2,550,365	217,932	2,530,164	225,108	2,509,178	232,007	25
26	2,709,596	210,692	2,691,017	219,294	2,671,591	227.621	2,651,329	235,669	2,630,241	243,425	2,608,336	250,880	26
27	2,812,925	227,176	2,793,550	236.445	2,773,294	245,421	2,752,169	254,094	2,730,186	262,452	2,707,352	270,485	27
28	2,916,151	244,275	2,895,973	254,239	2,874,881	263,885	2,852,883	273,205	2,829,993	282,187	2,806,220	290,819	28
29	3,019,276	261,991	2,998,285	272,672	2,976,343	283,013	2,953,462	293,004	2,929,657	302,631	2,904,936	311,882	29
30	3,122,294	280,321	3,100,478	291,745	3,077,677	302,805	3,053,906	313,488	3,029,174	323,781	3,003,493	333,672	30

TABLE I—Continued.

Longitude.	Latitude 26°.		Latitude 27°.		Latitude 28°.		Latitude 29°.		Latitude 30°.		Latitude 31°.		Longitude.
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	
°	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	°
1	100,105	383	99,242	393	98,349	403	97,426	412	96,474	421	95,491	429	1
2	200,204	1,532	198,478	1,573	196,692	1,612	194,845	1,649	192,940	1,684	190,975	1,717	2
3	300,291	3,446	297,702	3,538	295,021	3,626	292,250	3,709	289,391	3,788	286,444	3,862	3
4	400,361	6,127	396,907	6,290	393,330	6,446	389,635	6,594	385,821	6,735	381,889	6,866	4
5	500,407	9,573	496,086	9,828	491,614	10,072	486,991	10,303	482,221	10,522	477,304	10,728	5
6	600,424	13,784	595,235	14,152	589,864	14,503	584,313	14,836	578,585	15,151	572,680	15,447	6
7	700,406	18,760	694,346	19,260	688,074	19,738	681,593	20,192	674,904	20,620	668,010	21,024	7
8	800,347	24,501	793,414	25,155	786,238	25,778	778,824	26,370	771,172	26,930	763,285	27,457	8
9	900,241	31,007	892,431	31,835	884,350	32,623	875,999	33,372	867,381	34,080	858,499	34,747	9
10	1,000,083	38,277	991,392	39,298	982,402	40,271	973,111	41,194	963,524	42,068	953,644	42,891	10
11	1,099,865	46,310	1,090,293	47,545	1,080,388	48,722	1,070,153	49,839	1,059,594	50,896	1,048,712	51,891	11
12	1,199,583	55,107	1,189,124	56,576	1,178,302	57,976	1,167,120	59,305	1,155,583	60,562	1,143,694	61,744	12
13	1,299,232	64,666	1,287,881	66,389	1,276,136	68,031	1,264,003	69,590	1,251,484	71,064	1,238,584	72,452	13
14	1,398,804	74,988	1,386,556	76,985	1,373,886	78,888	1,360,795	80,695	1,347,290	82,404	1,333,375	84,012	14
15	1,498,296	86,070	1,485,145	88,362	1,471,542	90,546	1,457,490	92,619	1,442,994	94,579	1,428,057	96,423	15
16	1,597,697	97,914	1,583,640	100,520	1,569,100	103,003	1,554,080	105,360	1,538,587	107,588	1,522,625	109,685	16
17	1,697,006	110,518	1,682,036	113,458	1,666,552	116,259	1,650,559	118,918	1,634,063	121,432	1,617,069	123,797	17
18	1,796,215	123,882	1,780,326	127,175	1,763,893	130,313	1,746,920	133,292	1,729,415	136,108	1,711,382	138,757	18
19	1,895,320	138,004	1,878,505	141,672	1,861,115	145,165	1,843,156	148,481	1,824,635	151,615	1,805,557	154,564	19
20	1,994,313	152,884	1,976,565	156,944	1,958,212	160,812	1,939,260	164,484	1,919,715	167,953	1,899,587	171,217	20
21	2,093,191	168,521	2,074,502	172,994	2,055,178	177,255	2,035,225	181,300	2,014,650	185,120	1,993,463	188,715	21
22	2,191,946	184,914	2,172,308	189,819	2,152,005	194,492	2,131,044	198,925	2,109,432	203,115	2,087,177	207,056	22
23	2,290,571	202,061	2,269,978	207,419	2,248,689	212,521	2,226,710	217,362	2,204,053	221,936	2,180,723	226,238	23
24	2,389,063	219,963	2,367,505	225,791	2,345,221	231,342	2,322,218	236,608	2,298,506	241,583	2,274,093	246,261	24
25	2,487,415	238,619	2,464,884	244,937	2,441,596	250,953	2,417,558	256,661	2,392,784	262,052	2,367,279	267,122	25
26	2,585,622	258,026	2,562,108	264,853	2,537,807	271,354	2,512,727	277,520	2,486,879	283,345	2,460,273	288,819	26
27	2,683,677	278,184	2,659,172	285,539	2,633,848	292,541	2,607,715	299,183	2,580,786	305,456	2,553,070	311,352	27
28	2,781,575	299,092	2,756,067	306,993	2,729,711	314,516	2,702,516	321,649	2,674,496	328,387	2,645,660	334,719	28
29	2,879,310	320,749	2,852,791	329,214	2,825,392	337,275	2,797,124	344,918	2,768,001	352,134	2,738,036	358,916	29
30	2,976,877	343,150	2,949,335	352,201	2,920,883	360,817	2,891,631	368,985	2,861,297	376,697	2,830,192	383,943	30

TABLE I—Continued.

Longitude.	Latitude 32°.		Latitude 33°.		Latitude 34°.		Latitude 35°.		Latitude 36°.		Latitude 37°.		Longitude.
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	
°	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	°
1	94, 480	437	93, 441	444	92, 373	451	91, 276	457	90, 151	462	88, 999	467	1
2	188, 953	1, 748	186, 873	1, 776	184, 736	1, 803	182, 542	1, 827	180, 293	1, 850	177, 989	1, 869	2
3	283, 410	3, 932	280, 288	3, 997	277, 082	4, 057	273, 791	4, 112	270, 416	4, 161	266, 959	4, 206	3
4	377, 842	6, 990	373, 678	7, 105	369, 401	7, 211	365, 011	7, 309	360, 510	7, 398	355, 899	7, 477	4
5	472, 241	10, 921	467, 034	11, 101	461, 685	11, 267	456, 196	11, 419	450, 567	11, 558	444, 800	11, 681	5
6	566, 601	15, 725	560, 349	15, 984	553, 926	16, 223	547, 334	16, 443	540, 576	16, 642	533, 653	16, 821	6
7	660, 911	21, 402	653, 612	21, 754	646, 113	22, 079	638, 418	22, 378	630, 528	22, 649	622, 446	22, 893	7
8	755, 166	27, 950	746, 817	28, 410	738, 240	28, 835	729, 438	29, 225	720, 414	29, 579	711, 171	29, 897	8
9	849, 355	35, 370	839, 954	35, 952	830, 295	36, 488	820, 384	36, 982	810, 224	37, 430	799, 817	37, 833	9
10	943, 472	43, 661	933, 014	44, 378	922, 272	45, 041	911, 249	45, 650	899, 949	46, 202	888, 374	46, 699	10
11	1, 037, 509	52, 822	1, 025, 991	53, 689	1, 014, 160	54, 491	1, 002, 022	55, 226	989, 579	55, 895	976, 834	56, 495	11
12	1, 131, 456	62, 853	1, 118, 875	63, 884	1, 105, 953	64, 837	1, 092, 695	65, 711	1, 079, 104	66, 506	1, 065, 186	67, 219	12
13	1, 225, 308	73, 751	1, 211, 658	74, 960	1, 197, 640	76, 079	1, 183, 258	77, 104	1, 168, 517	78, 035	1, 153, 421	78, 870	13
14	1, 319, 054	85, 517	1, 304, 331	86, 919	1, 289, 213	88, 214	1, 273, 703	89, 402	1, 257, 806	90, 480	1, 241, 529	91, 449	14
15	1, 412, 687	98, 150	1, 396, 887	99, 757	1, 380, 663	101, 243	1, 364, 019	102, 605	1, 346, 963	103, 842	1, 329, 499	104, 952	15
16	1, 506, 199	111, 648	1, 489, 317	113, 475	1, 471, 982	115, 163	1, 454, 200	116, 711	1, 435, 979	118, 117	1, 417, 322	119, 377	16
17	1, 599, 583	126, 011	1, 581, 611	128, 071	1, 563, 160	129, 975	1, 544, 234	131, 720	1, 524, 842	133, 304	1, 504, 990	134, 725	17
18	1, 692, 829	141, 237	1, 673, 763	143, 544	1, 654, 189	145, 675	1, 634, 114	147, 628	1, 613, 546	149, 402	1, 592, 491	150, 993	18
19	1, 785, 932	157, 324	1, 765, 763	159, 893	1, 745, 061	162, 263	1, 723, 830	164, 437	1, 702, 080	166, 409	1, 679, 817	168, 179	19
20	1, 878, 880	174, 272	1, 857, 605	177, 113	1, 835, 766	179, 738	1, 813, 373	182, 142	1, 790, 434	184, 324	1, 766, 957	186, 281	20
21	1, 971, 669	192, 078	1, 949, 278	195, 206	1, 926, 297	198, 096	1, 902, 735	200, 741	1, 878, 600	203, 144	1, 853, 902	205, 297	21
22	2, 064, 289	210, 742	2, 040, 775	214, 171	2, 016, 644	217, 337	1, 991, 905	220, 237	1, 966, 569	222, 868	1, 940, 643	225, 225	22
23	2, 156, 733	230, 263	2, 132, 087	234, 004	2, 106, 800	237, 459	2, 080, 877	240, 623	2, 054, 330	243, 492	2, 027, 170	246, 064	23
24	2, 248, 991	250, 637	2, 223, 208	254, 704	2, 196, 754	258, 460	2, 169, 640	261, 899	2, 141, 876	265, 017	2, 113, 472	267, 810	24
25	2, 341, 058	271, 863	2, 314, 126	276, 270	2, 286, 499	280, 338	2, 258, 185	284, 062	2, 229, 196	287, 438	2, 199, 543	290, 461	25
26	2, 432, 923	293, 940	2, 404, 836	298, 699	2, 376, 026	303, 091	2, 346, 503	307, 110	2, 316, 281	310, 754	2, 285, 370	314, 015	26
27	2, 524, 579	316, 866	2, 495, 329	321, 989	2, 465, 328	326, 717	2, 434, 588	331, 042	2, 403, 123	334, 961	2, 370, 945	338, 470	27
28	2, 616, 020	340, 638	2, 585, 597	346, 138	2, 554, 394	351, 212	2, 522, 428	355, 854	2, 489, 711	360, 059	2, 456, 258	363, 822	28
29	2, 707, 241	365, 256	2, 675, 630	371, 144	2, 643, 217	376, 576	2, 610, 014	381, 544	2, 576, 038	386, 043	2, 541, 301	390, 068	29
30	2, 798, 228	390, 715	2, 765, 423	397, 009	2, 731, 788	402, 806	2, 697, 341	408, 110	2, 662, 093	412, 912	2, 626, 063	417, 207	30

TABLE I—Continued.

Longitude.	Latitude 38°.		Latitude 39°.		Latitude 40°.		Latitude 41°.		Latitude 42°.		Latitude 43°.		Longitude.
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	
°	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	°
1	87, 820	472	86, 614	476	85, 382	479	84, 123	481	82, 839	484	81, 529	485	1
2	175, 630	1, 887	173, 218	1, 903	170, 753	1, 916	168, 235	1, 926	165, 666	1, 935	163, 047	1, 941	2
3	263, 420	4, 246	259, 801	4, 281	256, 103	4, 310	252, 326	4, 334	248, 471	4, 353	244, 541	4, 367	3
4	351, 180	7, 548	346, 352	7, 610	341, 420	7, 662	336, 382	7, 705	331, 243	7, 738	326, 001	7, 762	4
5	438, 899	11, 793	432, 862	11, 889	426, 695	11, 971	420, 395	12, 038	413, 969	12, 090	407, 415	12, 127	5
6	526, 567	16, 980	519, 320	17, 118	511, 915	17, 236	504, 353	17, 332	496, 638	17, 407	488, 771	17, 461	6
7	614, 174	23, 109	605, 715	23, 297	597, 071	23, 456	588, 245	23, 587	579, 240	23, 690	570, 058	23, 763	7
8	701, 710	30, 179	692, 037	30, 424	682, 153	30, 632	672, 060	30, 803	661, 762	30, 936	651, 264	31, 032	8
9	789, 166	38, 189	778, 275	38, 499	767, 147	38, 762	755, 786	38, 978	744, 195	39, 146	732, 378	39, 267	9
10	876, 530	47, 138	864, 419	47, 520	852, 045	47, 845	839, 414	48, 111	826, 526	48, 317	813, 387	48, 466	10
11	963, 793	57, 026	950, 460	57, 487	936, 837	57, 879	922, 931	58, 200	908, 744	58, 451	894, 282	58, 630	11
12	1, 050, 945	67, 850	1, 036, 385	68, 399	1, 021, 510	68, 865	1, 006, 327	69, 246	990, 839	69, 541	975, 050	69, 755	12
13	1, 137, 976	79, 611	1, 122, 186	80, 254	1, 106, 055	80, 799	1, 089, 591	81, 246	1, 072, 798	81, 593	1, 055, 680	81, 841	13
14	1, 224, 875	92, 306	1, 207, 851	93, 050	1, 190, 461	93, 681	1, 172, 713	94, 198	1, 154, 610	94, 600	1, 136, 160	94, 887	14
15	1, 311, 633	105, 934	1, 293, 371	106, 787	1, 274, 717	107, 509	1, 255, 680	108, 101	1, 236, 266	108, 561	1, 216, 479	108, 889	15
16	1, 398, 239	120, 493	1, 378, 733	121, 462	1, 358, 813	122, 282	1, 338, 484	122, 953	1, 317, 753	123, 475	1, 296, 627	123, 846	16
17	1, 484, 684	135, 982	1, 463, 931	137, 073	1, 442, 738	137, 997	1, 421, 111	138, 753	1, 399, 060	139, 339	1, 376, 590	139, 756	17
18	1, 570, 957	152, 400	1, 548, 951	153, 620	1, 526, 481	154, 653	1, 503, 552	155, 497	1, 480, 176	156, 152	1, 456, 357	156, 616	18
19	1, 657, 049	169, 742	1, 633, 784	171, 099	1, 610, 031	172, 247	1, 585, 796	173, 184	1, 561, 090	173, 911	1, 535, 920	174, 425	19
20	1, 742, 950	188, 010	1, 718, 421	189, 509	1, 693, 379	190, 777	1, 667, 833	191, 812	1, 641, 791	192, 614	1, 615, 264	193, 180	20
21	1, 828, 650	207, 199	1, 802, 850	208, 848	1, 776, 514	210, 241	1, 749, 651	211, 378	1, 722, 270	212, 258	1, 694, 380	212, 877	21
22	1, 914, 138	227, 308	1, 887, 062	229, 112	1, 859, 426	230, 637	1, 831, 238	231, 880	1, 802, 512	232, 840	1, 773, 254	233, 516	22
23	1, 999, 405	248, 334	1, 970, 045	250, 301	1, 942, 103	251, 961	1, 912, 587	253, 314	1, 882, 509	254, 358	1, 851, 878	255, 091	23
24	2, 084, 442	270, 275	2, 054, 791	272, 410	2, 024, 537	274, 212	1, 993, 684	275, 679	1, 962, 249	276, 809	1, 930, 240	277, 602	24
25	2, 169, 237	293, 129	2, 138, 290	295, 439	2, 106, 714	297, 386	2, 074, 520	298, 970	2, 041, 721	300, 189	2, 008, 328	301, 042	25
26	2, 253, 782	316, 893	2, 221, 530	319, 382	2, 188, 627	321, 481	2, 155, 084	323, 186	2, 120, 915	324, 496	2, 086, 132	325, 410	26
27	2, 338, 068	341, 564	2, 304, 504	344, 239	2, 270, 264	346, 492	2, 235, 366	348, 322	2, 199, 820	349, 727	2, 163, 640	350, 703	27
28	2, 422, 083	367, 138	2, 387, 197	370, 005	2, 351, 617	372, 418	2, 315, 354	374, 376	2, 278, 425	375, 877	2, 240, 841	376, 917	28
29	2, 505, 819	393, 615	2, 469, 603	396, 678	2, 432, 673	399, 256	2, 395, 038	401, 344	2, 356, 718	402, 943	2, 317, 726	404, 048	29
30	2, 589, 264	420, 989	2, 551, 712	424, 258	2, 513, 422	427, 000	2, 474, 408	429, 223	2, 434, 691	430, 921	2, 394, 281	432, 092	30

TABLE I—Continued.

Longitude.	Latitude 44°		Latitude 45°		Latitude 46°		Latitude 47°		Latitude 48°		Latitude 49°		Longitude.
	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	
°	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	°
1	80,194	486	78,835	486	77,452	486	76,045	485	74,614	484	73,161	482	1
2	160,377	1,944	157,659	1,946	154,892	1,945	152,077	1,941	149,216	1,935	146,309	1,927	2
3	240,536	4,375	236,458	4,378	232,307	4,375	228,085	4,368	223,792	4,354	219,432	4,336	3
4	320,660	7,777	315,221	7,782	309,685	7,778	304,055	7,764	298,331	7,740	292,516	7,708	4
5	400,737	12,150	393,936	12,158	387,015	12,152	379,976	12,130	372,820	12,093	365,550	12,042	5
6	480,754	17,494	472,591	17,505	464,284	17,495	455,835	17,464	447,246	17,411	438,521	17,338	6
7	560,702	23,807	551,175	23,823	541,480	23,809	531,619	23,766	521,597	23,695	511,415	23,594	7
8	640,566	31,089	629,674	31,109	618,590	31,091	607,317	31,035	595,860	30,942	584,220	30,810	8
9	720,337	39,339	708,078	39,364	695,603	39,341	682,916	39,270	670,022	39,151	656,925	38,985	9
10	800,001	48,556	786,373	48,586	772,506	48,557	758,404	48,469	744,073	48,322	729,515	48,116	10
11	879,549	58,737	864,549	58,774	849,287	58,738	833,768	58,631	817,997	58,452	801,979	58,203	11
12	958,967	69,883	942,594	69,925	925,935	69,882	908,997	69,754	891,784	69,541	874,303	69,243	12
13	1,038,243	81,990	1,020,495	82,039	1,002,437	81,987	984,077	81,836	965,421	81,584	946,476	81,235	13
14	1,117,367	95,058	1,098,239	95,113	1,078,780	95,052	1,058,997	94,876	1,038,896	94,584	1,018,485	94,177	14
15	1,196,327	109,084	1,175,817	109,145	1,154,953	109,074	1,133,745	108,871	1,112,197	108,534	1,090,317	108,065	15
16	1,275,112	124,066	1,253,215	124,134	1,230,945	124,053	1,208,307	123,819	1,185,309	123,434	1,161,959	122,899	16
17	1,353,708	140,002	1,330,423	140,077	1,306,742	139,982	1,282,673	139,717	1,258,223	139,281	1,233,401	138,676	17
18	1,432,106	156,890	1,407,428	156,972	1,382,334	156,863	1,356,830	156,563	1,330,925	156,072	1,304,628	155,392	18
19	1,510,294	174,727	1,484,219	174,816	1,457,707	174,691	1,430,766	174,354	1,403,403	173,805	1,375,629	173,044	19
20	1,588,258	193,511	1,560,784	193,605	1,532,851	193,465	1,504,467	193,088	1,475,645	192,476	1,446,391	191,631	20
21	1,665,990	213,238	1,637,111	213,339	1,607,754	213,180	1,577,926	212,761	1,547,639	212,083	1,516,902	211,147	21
22	1,743,477	233,907	1,713,189	234,013	1,682,402	233,834	1,651,126	233,370	1,619,372	232,622	1,587,150	231,591	22
23	1,820,708	255,514	1,789,006	255,624	1,756,786	255,423	1,724,058	254,912	1,690,833	254,090	1,657,123	252,958	23
24	1,897,670	278,055	1,864,550	278,169	1,830,893	277,945	1,796,708	277,382	1,762,009	276,482	1,726,808	275,246	24
25	1,974,355	301,527	1,939,811	301,645	1,904,711	301,395	1,869,066	300,779	1,832,889	299,796	1,796,193	298,449	25
26	2,050,748	325,928	2,014,775	326,048	1,978,228	325,770	1,941,119	325,097	1,903,461	324,027	1,865.267	322,564	26
27	2,126,840	351,253	2,089,434	351,373	2,051,435	351,067	2,012,856	350,332	1,973,712	349,172	1,934,017	347,587	27
28	2,202,620	377,498	2,163,773	377,619	2,124,317	377,280	2,084,265	376,481	2,043,631	375,225	2,002,432	373.513	28
29	2,278,076	404,661	2,237,784	404,780	2,196,866	404,406	2,155,335	403,540	2,113,207	402,183	2,070,500	400,338	29
30	2,353,197	432,736	2,311,449	432,852	2,269,067	432,441	2,226,052	431,504	2,182,427	430,042	2,138,207	428,058	30

TABLE I—Continued.

Longitude.	Latitude 50°.		Latitude 51°.		Latitude 52°.		Latitude 53°.		Latitude 54°.		Longitude.
	X	Y	X	Y	X	Y	X	Y	X	Y	
°	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*	°
1	71, 685	479	70, 186	476	68, 667	472	67, 127	468	65, 567	463	1
2	143, 357	1, 917	140, 360	1, 904	137, 322	1, 888	134, 241	1, 871	131, 117	1, 851	2
3	215, 003	4, 312	210, 510	4, 284	205, 950	4, 249	201, 329	4, 210	196, 645	4, 165	3
4	286, 611	7, 666	280, 618	7, 614	274, 541	7, 553	268, 378	7, 483	262, 131	7, 404	4
5	358, 168	11, 976	350, 676	11, 896	343, 078	11, 801	335, 375	11, 692	327, 566	11, 567	5
6	429, 661	17, 243	420, 671	17, 126	411, 549	16, 990	402, 304	16, 832	392, 937	16, 654	6
7	501, 077	23, 465	490, 586	23, 307	479, 946	23, 120	469, 157	22, 906	458, 226	22, 664	7
8	572, 403	30, 641	560, 411	30, 434	548, 249	30, 192	535, 920	29, 911	523, 427	29, 595	8
9	643, 627	38, 771	630, 133	38, 510	616, 451	38, 202	602, 576	37, 845	588, 521	37, 445	9
10	714, 736	47, 851	699, 742	47, 530	684, 534	47, 146	669, 119	46, 707	653, 500	46, 212	10
11	785, 718	57, 882	769, 219	57, 490	752, 487	57, 030	735, 530	56, 498	718, 347	55, 899	11
12	856, 558	68, 861	838, 555	68, 398	820, 300	67, 845	801, 798	67, 215	783, 052	66, 497	12
13	927, 246	80, 786	907, 736	80, 240	887, 956	79, 592	867, 910	78, 850	847, 602	78, 010	13
14	997, 768	93, 655	976, 753	93, 020	955, 446	92, 270	933, 854	91, 407	911, 980	90, 431	14
15	1, 068, 111	107, 465	1, 045, 588	106, 733	1, 022, 753	105, 873	999, 614	104, 880	976, 178	103, 765	15
16	1, 138, 264	122, 215	1, 114, 230	121, 382	1, 089, 866	120, 401	1, 065, 180	119, 274	1, 040, 184	118, 002	16
17	1, 208, 213	137, 902	1, 182, 670	136, 963	1, 156, 777	135, 850	1, 130, 540	134, 578	1, 103, 977	133, 140	17
18	1, 277, 946	154, 522	1, 250, 890	153, 465	1, 223, 466	152, 219	1, 195, 684	150, 791	1, 167, 554	149, 178	18
19	1, 347, 451	172, 073	1, 318, 880	170, 893	1, 289, 926	169, 504	1, 260, 594	167, 908	1, 230, 894	166, 110	19
20	1, 416, 715	190, 552	1, 386, 627	189, 240	1, 356, 139	187, 699	1, 325, 260	185, 930	1, 293, 993	183, 936	20
21	1, 485, 725	209, 955	1, 454, 119	208, 503	1, 422, 005	206, 804	1, 389, 665	204, 853	1, 356, 834	202, 650	21
22	1, 554, 471	230, 279	1, 521, 346	228, 686	1, 487, 785	226, 818	1, 453, 800	224, 670	1, 419, 401	222, 250	22
23	1, 622, 938	251, 520	1, 588, 290	249, 775	1, 553, 192	247, 726	1, 517, 653	245, 381	1, 481, 688	242, 732	23
24	1, 691, 115	273, 675	1, 654, 943	271, 771	1, 618, 307	269, 540	1, 581, 213	266, 977	1, 543, 671	264, 092	24
25	1, 758, 990	296, 739	1, 721, 292	294, 670	1, 683, 114	292, 242	1, 644, 465	289, 457	1, 605, 360	286, 323	25
26	1, 826, 550	320, 709	1, 787, 322	318, 465	1, 747, 603	315, 836	1, 707, 398	312, 820	1, 666, 725	309, 430	26
27	1, 893, 784	345, 580	1, 853, 027	343, 153	1, 811, 762	340, 312	1, 769, 999	337, 055	1, 727, 754	333, 393	27
28	1, 960, 680	371, 347	1, 918, 390	368, 730	1, 875, 577	365, 669	1, 832, 256	362, 163	1, 788, 440	358, 218	28
29	2, 027, 224	398, 006	1, 983, 398	395, 193	1, 939, 040	391, 900	1, 894, 155	388, 131	1, 848, 761	383, 897	29
30	2, 093, 407	425, 553	2, 048, 043	422, 532	2, 002, 133	418, 984	1, 955, 688	414, 965	1, 908, 730	410, 425	30

TABLE II.

Length, in metres, of one degree of latitude and longitude, from latitude 20° to 54°; values of the corresponding radii of the developed parallel, and angles at each pole for 10° of longitude.

Lat.	1° of latitude.	1° of longitude.	Radius of parallel.	θ for 10° of longitude.
°	*Metres.*	*Metres.*	*Metres.*	° ′ ″
20	110 693.3	104 634.8	17 528 600	3 25 12.7
21	110 706.0	103 958.2	16 620 820	35 01.3
22	110 719.2	103 250.0	15 792 110	44 45.8
23	110 732.9	102 510.5	15 031 865	54 26.3
24	110 747.1	101 739.8	14 331 780	4 04 02.5
25	110 761.7	100 938.2	13 684 530	13 34.3
26	110 776.7	100 105.9	13 083 990	23 01.4
27	110 792.2	99 243.2	12 524 960	32 23.7
28	110 808.1	98 350.2	12 002 960	41 41.0
29	110 824.4	97 427.4	11 524 770	50 53.1
30	110 841.0	96 474.8	11 055 200	5 00 00.0
31	110 858.0	95 492.9	10 623 179	09 01.4
32	110 875.2	94 481.9	10 215 570	17 57.1
33	110 892.8	93 442.1	9 830 067	26 47.0
34	110 910.7	92 373.8	9 464 760	35 31.0
35	110 928.8	91 277.3	9 117 882	44 08.8
36	110 947.2	90 152.9	8 787 972	52 40.3
37	110 965.8	89 001.0	8 473 340	6 01 05.3
38	110 984.6	87 821.9	8 173 042	09 23.8
39	111 003.5	86 616.0	7 885 875	17 35.5
40	111 022.6	85 383.6	7 610 788	25 40.4
41	111 041.8	84 125.1	7 346 915	33 38.1
42	111 061.1	82 840.8	7 093 423	41 28.7
43	111 080.5	81 531.1	6 849 560	49 11.9
44	111 100.0	80 196.5	6 614 648	56 47.7
45	111 119.4	78 837.3	6 388 064	7 04 15.8
46	111 138.9	77 453.9	6 169 244	11 36.2
47	111 158.4	76 046.8	5 957 663	18 48.7
48	111 177.8	74 616.3	5 752 845	25 53.2
49	111 197.2	73 162.9	5 554 355	32 49.6
50	111 216.4	71 687.0	5 361 781	39 37.6
51	111 235.6	70 189.1	5 174 752	46 17.3
52	111 254.6	68 669.6	4 992 925	52 48.4
53	111 273.4	67 129.0	4 815 973	59 10.9
54	111 292.1	65 567.7	4 643 603	8 05 24.6

TABLE III.—A.

Table for converting metres into statute miles.

1 metre = 0.000621346 mile.

[6.7933335.]

Metres.	Miles.	Metres.	Miles.	Metres.	Miles.	Metres.	Miles.
100000	62.135						
90000	55.921	9000	5.592	900	.559	90	.056
80000	49.708	8000	4.971	800	.497	80	.050
70000	43.494	7000	4.349	700	.435	70	.044
60000	37.281	6000	3.728	600	.373	60	.037
50000	31.067	5000	3.107	500	.311	50	.031
40000	24.854	4000	2.485	400	.249	40	.025
30000	18.640	3000	1.864	300	.186	30	.019
20000	12.427	2000	1.243	200	.124	20	.012
10000	6.213	1000	.621	100	.062	10	.006

TABLE III.—B.

Table for converting statute miles into metres.

1 mile = 1609.40831 metres.

[3.2066665.]

Miles.	Metres.	Miles.	Metres.	Miles.	Metres.	Miles.	Metres.
100	160940.83						
90	144846.75	9	14484.68	0.9	1448.47	0.09	144.85
80	128752.66	8	12875.27	0.8	1287.53	0.08	128.75
70	112658.58	7	11265.86	0.7	1126.59	0.07	112.66
60	96564.50	6	9656.45	0.6	965.65	0.06	96.56
50	80470.41	5	8047.04	0.5	804.70	0.05	80.47
40	64376.33	4	6437.63	0.4	643.76	0.04	64.38
30	48282.25	3	4828.23	0.3	482.82	0.03	48.28
20	32188.17	2	3218.82	0.2	321.88	0.02	32.19
10	16094.08	1	1609.41	0.1	160.94	0.01	16.09

TABLE III.—C.

Table for converting metres into yards.

1 metre = 1.09356959 yard.

[0.0388464.]

Metres.	Yards.	Metres.	Yards.	Metres.	Yards.	Metres.	Yards.	Metres.	Yards.
100000	109356.96								
90000	98421.26	9000	9842.13	900	984.21	90	98.42	9	9.84
80000	87485.57	8000	8748.56	800	874.86	80	87.49	8	8.75
70000	76549.87	7000	7654.99	700	765.50	70	76.55	7	7.65
60000	65614.18	6000	6561.42	600	656.14	60	65.61	6	6.56
50000	54678.48	5000	5467.85	500	546.79	50	54.68	5	5.47
40000	43742.78	4000	4374.28	400	437.43	40	43.74	4	4.37
30000	32807.09	3000	3280.71	300	328.07	30	32.81	3	3.28
20000	21871.39	2000	2187.14	200	218.71	20	21.87	2	2.19
10000	10935.70	1000	1093.57	100	109.36	10	10.94	1	1.09

TABLE III.—D.

Table for converting yards into metres.

1 yard = 0.91443654 metre.

[9.9611536.]

Yards.	Metres.	Yards.	Metres.	Yards.	Metres.	Yards.	Metres.	Yards.	Metres.
100000	91443.65								
90000	82299.29	9000	8229.93	900	822.99	90	82.30	9	8.23
80000	73154.92	8000	7315.49	800	731.55	80	73.16	8	7.32
70000	64010.56	7000	6401.06	700	640.11	70	64.01	7	6.40
60000	54866.19	6000	5486.62	600	548.66	60	54.87	6	5.49
50000	45721.83	5000	4572.18	500	457.22	50	45.72	5	4.57
40000	36577.46	4000	3657.75	400	365.78	40	36.58	4	3.66
30000	27433.10	3000	2743.31	300	274.33	30	27.43	3	2.74
20000	18288.73	2000	1828.87	200	182.89	20	18.29	2	1.83
10000	9144.37	1000	914.44	100	91.44	10	9.14	1	0.91

TABLE III.—E.

Table for converting yards into miles.

1 yard = 0.000568182 mile.

[6. 7544873.]

Yards.	Miles.	Yards.	Miles.	Yards.	Miles.	Yards.	Miles.
100000	56. 818						
90000	51. 136	9000	5. 114	900	0. 511	90	0. 051
80000	45. 455	8000	4. 545	800	. 455	80	. 045
70000	39. 773	7000	3. 977	700	. 398	70	. 040
60000	34. 091	6000	3. 409	600	. 341	60	. 034
50000	28. 409	5000	2. 841	500	. 284	50	. 028
40000	22. 727	4000	2. 273	400	. 227	40	. 023
30000	17. 045	3000	1. 705	300	. 170	30	. 017
20000	11. 364	2000	1. 136	200	. 114	20	. 011
10000	5. 682	1000	0. 568	100	. 057	10	. 006

TABLE IV.

Length of a degree of the meridian, in nautical and statute miles, for each fifth degree of latitude between 20° and 50°.

1° of latitude.	In latitude.	1° of latitude.
Nautical miles.	°	*Statute miles.*
59. 669	20	68. 779
59. 706	25	68. 822
59. 749	30	68. 871
59. 796	35	68. 925
59. 847	40	68. 984
59. 899	45	69. 044
59. 951	50	69. 104

TABLE V.

Length of a degree of longitude, for each degree of latitude from 19° to 54°, expressed in nautical and statute miles.

1° of the equator = 60 nautical miles = 69.160 statute miles = 111, 306. 6 metres.

1° of longitude.		In latitude.		1° of longitude.	
Statute miles.	Nautical miles.	°	°	Nautical miles.	Statute miles.
65. 415	56. 751	19	37	47. 976	55. 300
65. 015	56. 404	20	38	47. 341	54. 568
64. 594	56. 039	21	39	46. 690	53. 819
64. 154	55. 657	22	40	46. 026	53. 053
63. 695	55. 259	23	41	45. 348	52. 271
63. 216	54. 843	24	42	44. 656	51. 473
62. 718	54. 411	25	43	43. 949	50. 659
62. 200	53. 962	26	44	43. 230	49. 830
61. 664	53. 497	27	45	42. 498	48. 986
61. 109	53. 016	28	46	41. 752	48. 126
60. 536	52. 518	29	47	40. 993	47. 251
59. 944	52. 005	30	48	40. 222	46. 362
59. 334	51. 476	31	49	39. 439	45. 460
58. 706	50. 931	32	50	38. 643	44. 542
58. 060	50. 370	33	51	37. 835	43. 612
57. 396	49. 794	34	52	37. 016	42. 668
56. 715	49. 203	35	53	36. 186	41. 710
56. 016	48. 597	36	54	35. 344	40. 740

TABLE VI.

Radii and co-ordinates for the polyconic development of a sphere, the radius of the sphere being assumed = 1.

Latitude.	x.	y.	Length of 10° of parallel.	Radius of parallel.
°				
0	3.142	0.000	0.1745	Inf.
10	2.942	0.823	0.1719	5.671
20	2.416	1.439	0.1640	2.747
30	1.732	1.732	0.1512	1.732
40	1.074	1.709	0.1337	1.192
50	0.563	1.461	0.1122	0.839
60	0.236	1.104	0.0873	0.577
70	0.069	0.721	0.0597	0.364
80	0.008	0.352	0.0303	0.176
85	0.001	0.175	0.0152	0.087
90	0.000	0.000	0.0000	0.000

Primary Triangulation Sect.ⁿ

	From where to where	Dir.	Course	Sines	Cosines
1	Hill to Webb	N E	39. 46. 59	9.8061002	9. 8856285
	" " Stabler	N.W	20. 04. 28	9.5355931	9. 9727800
	" " Sugar Loaf	"	47. 32. 44	9.8679470	9. 8293062
	" " Peach Grove	"	85. 21. 26	9.9985726	8. 9081799
	" " Capitol	S.W	85. 03. 00	9.9983772	8. 9359422
2	Stabler to Webb	S.E	82. 44. 49	9.9965109	9. 1012378
	" " Capitol	S.W	4. 43. 45	8.9161688	9. 9985189
	" " Peach Grove	"	43. 35. 35	9.8385543	9. 8598918
	" " Bull Run	"	67. 06. 48	9.9643897	9.5898486
	" " Md. Hts.	N.W	68. 36. 34	9.9690038	9.5619635
	" " Sugar Loaf	"	65. 54. 46	9.9604352	9.6107952
3	Peach Grove to Bull Run	S.W	84. 24. 38	9.9979302	8. 9885569
	" " " Md. Hts.	N.W.	41. 39. 17	9.8225795	9.8734214
	" " " Sugar Loaf	"	20. 11. 58	9.5381657	9.9724349
	" " " Capitol	S.E	79. 49. 45	9.9931211	9. 2269506

Table Nº 2

	N. Metres	S. Metres	E. Metres
Hill	00.0	00.0	00.0
Webb	21347.6		17775.5
Stabler	24761.6		
Peach Grove	2459.2		
Capitol		968.1	
Sugar Loaf	40511.9		
Bull Run		1566.3	
Md. Hts.	49452.7		

Linear Co-ordinates. Table No. 1.

Distances	Log. Do.	Lats.	Log. Do.	Deps.	Log. Do.
	4.4437204	21347.6	4.3293489	17775.5	4.2498206
	4.4209998	24761.7	4.3937798	9048.8	3.9565929
	4 7782798	40511.4	4.6075860	44281.2	4.6462268
	4.4826114	2459.2	3.3907916	30282.0	4.4811843
	4.0499657	968.1	2.9859079	11177.5	4.0483429
	4.4320169	3413.9	3.5332548	26824.3	4.4285279
	4 4119166	25729.7	4.4104355	2128.6	3.3280854
	4.4884579	22302.3	4.3483497	21233.0	4.3270122
	4.8305536	26327.9	4.4204032	62367.4	4.7949443
	4.8305750	24691.1	4.3925382	63034.8	4.7995785
	4.5865108	15750.7	4.1973060	35232.3	4.5469460
	4.6162537	4025.6	3.6048311	41134.3	4.6142044
	4.7986134	46993.4	4.6720369	41801.8	4.6211950
	4.6079558	38052.6	4.5803845	13999.6	4.1461153
	4.2880142	3427.4	3.5349648	19104.5	4.2811353

W.
Metres
00.0

9048.8
30281.9
11177.4
44281.2
71416.2
72083.6

792 00

742 30
126 00
86. 830
123 50
991 80

20
8
743 40

Explanation of Tables

In Table (1) the directions at Hill △ are true observed angles with the meridian of Hill, but at Stabler and Peach Grove the directions are angles with a line parallel to the meridian of Hill obtained from the directions ~~from~~ at Hill reversed, and the observed angles. thus; the observed angle at Stabler between Hill & Webb is 62°. 40′. 21″ and the bearing Hill-Stabler reversed is S. E., 20°. 04′. 28″. The sum is Stabler to Webb S.E. 82°. 44′. 49″ and the whole of the courses in Table 1. are thus found. The Log. distances are from the triangle sides, & the Logs. of Lats. & Deps. are respectively, Log. Dist. + Log. Cos. of Course & Log. Dist + Log. Sin. of Course.

Having found the Latitudes and Departures on each Course, Table 2 is formed from them, assuming Hill as zero and taking Webb as determined by the first Course. Stabler is then found from Hill and Webb! from Hill direct and from Webb by reversing the first course from Stabler, thus, Webb is

21347.6 North, and 17775.5 East of Hill
Stabler is + $\underbrace{3413.9}$ North, and + $\underbrace{26824.3}$ West of Webb
Which gives Stabler, 24761.5 North, and, 9048.8 West of Hill
t by Course (2) from Hill, Stabler = 24761.7 North, & 9048.8 " " "

The mean of these two, is then placed in Table (2) as the true position of Stabler, and is used to determine, Peach Grove from Hill and Stabler. Then the Capitol is fixed from Hill Stabler and Peach Grove, and Sugar Loaf from the same three stations. Bull Run and Ind. Hts. are fixed from Stabler and Peach Grove and so the table may be extended over a large area.

Having got the relative positions, in metres, of all the Stations of the △n. if I wish to know whether one point will see another about which I am doubtful, or between which I wish to open a line, I have from Table (2) two legs of a right angled triangle of which the Course (parallel to meridian of Hill) is one angle and the distance

between the two Stations is the hypothenuse; thus here is case which occurred last November. Being at Bull Run wished to know if I could see the Capitol at Washington.

From Table (2) I had.

Capitol = $968^{m}.1$ South $11177^{m}.4$ West of Hill
Bull Run = 1566.3 South 71416.2 " " "
Whence Capitol = 598.2 North 60238.8 East of Bull Run

60238.8 = 4.7798765
598.2 = 2.7768464
Bull Run to Capitol N.E. $89^\circ.25'.52''$ Tang. = 2.0030301
Sin. = 9.9999786
Distance Do to Do. $60241^{m}.8$ = 4.7798979

From Table (1), Bull Run to Peach Grove N.E. $84^\circ.24'.38''$
By above Comp. " " " Capitol N.E. 89.25.52
Angle at Bull Run between Peach Grove & Capitol 5.01.14

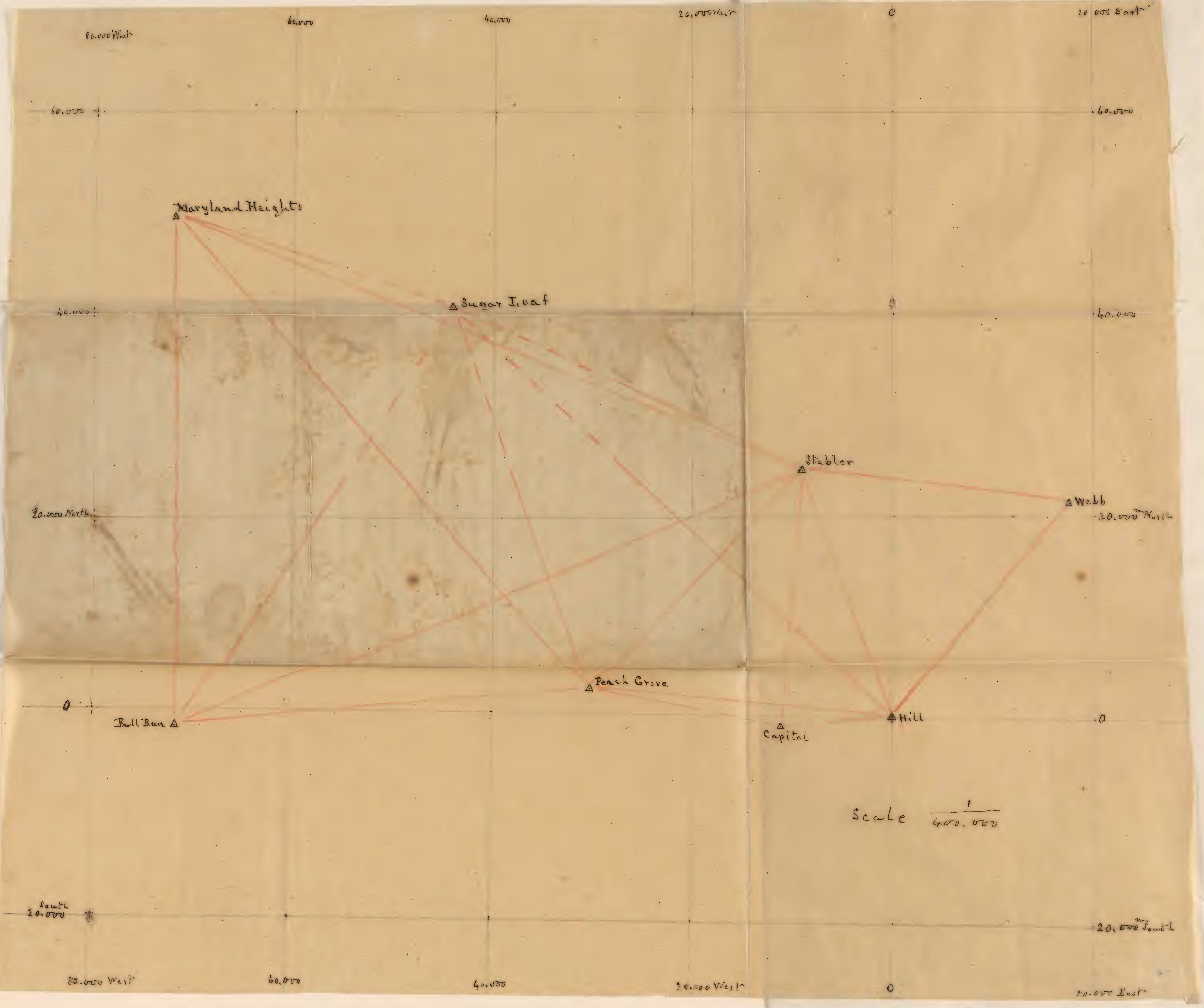
which laid off on the instrument gave me the direction I sought. If you have no observed or computed meridian to start with, assume a direction for some convenient side of a triangle and compute your courses and distances upon the assumed direction as a main ordinate. The error will not be appreciable in one seasons work of Sec. △n. in the South. The first Top. Survey of Charleston Harbor was made in this manner before any observations for L. M. Z. had been made. Most probably you have made similar surveys.

The tracing from my projection for reconnaissance which I enclose is similarly made. Each square is 20.000 metres on a side, & the stations are plotted in their proper squares from the positions in Table (2).

Indeed in all my reconnaissances my first efforts are devoted to forming an approx. table of the kind. Then if I go on a wooded hill and wish to cut out to a distant point of my scheme, which may or may not be visible, I first compute its direction from Table (2)

then lay off that direction and open the line. In th
way I have saved much labor & time and many
dollars.

C. O. Boutelle


80.000 West
60.000
40.000
20.000 West
0
20 000 East
60.000
60.000
Maryland Heights
Sugar Loaf
40.000
40.000
Stabler
Webb
20.000 North
20.000 m North
Peach Grove
0
Bull Run
Capitol
Hill
0
Scale 1/400.000
South 20.000
20.000 m South
80.000 West
60.000
40.000
20.000 West
0
20.000 East

Hydrographic Work.

In executing hydrography in wide places, it is best to run parallel lines from bank to bank, and other parallels crossing them at right angles, regulated according to the course of the channel. In narrow places, diagonals from shore to shore should be run, one line square across and one diagonal, alternately

Sometimes it is well to run parallels at right angles to the cross-lines up and down stream. The closeness of these lines of course depends on the character of the bottom, regular bottoms not requiring as many lines as irregular ones.

Generally where there are very narrow channels running in broad sheets of water, diagonals from side to side of the channel, besides the parallel lines, are advisable. Lines can be ended at the topographical stations without angles. Angles can be taken on the topographical stations sufficiently close to determine the lines up and down stream parallel to the banks. One tide guage will be sufficient for a sheet generally, if there is only one way in which the tide runs; but if the tide run from two different inlets, and meet in the sheet, of course there must be a guage for each set of tides. If there is a regul

l tides day and night, it is sufficient to read the day
h and low waters, besides taking readings while at work
n the boat. Fourteen days low water will give a fair
mean, but a month or even a longer time is still better.

Four men as oarsmen will be needed for the hydrography, and one lead-man and two officers in the boat one of the latter to steer and take angles, the other to record and take angles. This supposes very few angles necessary, otherwise three officers will be needed in the boat, one to record. In regard to office work, a duplicate should be kept of the sounding books and tide books, with, of course, duplicate records of the angles taken. After a good, mean low water has been determined, all the soundings should be reduced to mean low water on the original note book, but not copied in the duplicate.

It is necessary only to plot the angles and lines of sounding on the sheet, leaving the soundings to be plotted at the Office.

The angle marks should be inked in, in red on the sheet

A table of statistics showing the date and number of angles, the number of soundings, and the number of miles of each day's work, and what officers were in the boat on each day, should be put upon the sheet. The total on the sheet should be added up, in black, ink, of course.

A "fair journal" should be kept as usual